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SCIENCE AND TECHNOLOGY

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JAPAN REPORT

SCIENCE AND TECHNOLOGY

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AEROSPACE SCIENCES

INTEGRATION OF SPACE DEVELOPMENT ORGANIZATION URGED

Tokyo SENTAKU in Japanese Jul 86 pp 120-121

[Article: "Unorganized Space Development Program; Japan Will Lag Increasingly Behind Other Countries Unless Something Is Done"]

[Text] With the prospective advent of the era of commercial use of space, the jurisdiction rivalry between competent government agencies over Japan's development and utilization of space has begun to intensify.

Japan's development of space is conducted by a setup headed by the Space Development Committee, which is an adviser to the prime minister, and it plans, deliberates, and decides important matters concerning space development (its chairmanship is concurrently held by the director general of the Science and Technology Agency). Its executive organizations are the Institute of Space and Astronautical Science, the Ministry of Education (formerly, the Institute of Space and Aeronautics of Tokyo University), which is in charge of scientific observation, and the National Space Development Agency of Japan (NASDA), which is in charge of practical utilization. It has the cooperation of such related organizations as the Science and Technology Agency, the Ministry of Posts and Telecommunications, the Ministry of International Trade and Industry, the Ministry of Transport, and universities.

Japan is the only country that handles space development on a dual basis--science and practical utilization. Moreover, the Japanese technical level in space development is far behind as a whole, although some of its technology excels that in the advanced countries of Europe and the United States. Under these circumstances, the necessity of unifying the nation's space development setup and conducting space development and utilization efficiently is stated every now and then. Yet, no realization of this is in sight.

On the contrary, the approach of the era of commercial utilization of space is increasing the voice of the Ministry of Posts and Telecommunications and the Ministry of International Trade and Industry, which are in a position to use the results of space development, and these ministries now wield tremendous influence in policy decision of the Space Development Committee.

Space is a fascinating new world with infinite possibilities, and therefore different agencies hold different wishes for it. The Ministry of Education requires a free hand from the standpoint of freedom of learning, the Science and Technology Agency eagerly engages in technical development on Japan's own to catch up with the advanced nations of Europe and the United States, and the Ministry of Posts and Telecommunications and the Ministry of International Trade and Industry, watching carefully for world trends, eagerly try not to "miss the bus" in the era of commercial utilization of space.

Space is said to be the stage for the industrial revolution of the 21st century, and the United States, the Soviet Union, and the European countries stress manned space activities in their efforts to develop and use space. However, the present Japanese space development setup is not nationally integrated. Instead, it threatens to be increasingly diversified as the result of the conflicting wishes of the government agencies and their worsened jurisdiction strife. Can Japan, in this situation, ever ride the tidal current of the world?

Tug-of-War Between Science and Commercial Use

First of all, Japan's conduct of space development on the dual basis of science and commercial use is the result of a tug-of-war between the Ministry of Education, which requires freedom of learning for its Institute of Space and Astronautical Science, which is central to its space development, and the Science and Technology Agency, which wants to seize leadership in the national effort at space development for its NASDA and National Aerospace Laboratory.

It was the Institute of Space and Aeronautics of Tokyo University established in April 1964 that pioneered space development in Japan. This institute carried out space development activities consistently using Japanese technology and launched the nation's first artificial satellite, Osumi, in February 1970, and has since launched a total of 15 scientific research satellites, including Suisei, which played a vital role in observing Halley's comet. The institute's research results are highly appreciated internationally.

Meanwhile NASDA, which is in charge of the area of practical use, was established in October 1969 as the central executive organization for Japan's space development. Unlike Tokyo University, NASDA adopted a policy to accumulate Japanese technology while basically preferring to adopt American technology in order to be able to rush the development of practical utilization in which Japan then lagged behind certain foreign countries. It succeeded in launching the technical research satellite Kiku No 1 in September 1975 and has since launched a total of 17 application satellites, including the meteorological satellite Himawari.

There has been a persistent demand that the Institute of Space and Aeronautics and NASDA be unified to ensure the efficient conduct of Japan's space development. Yet, this has not been realized to this day for the following two

reasons, aside from the wishes of the Ministry of Education and the Science and Technology Agency.

First is the fact that when the Space Development Headquarters, the predecessor of NASDA, was established in the Science and Technology Agency, Prime Minister Nakasone, then chairman of the Space Development Subcommittee, Science and Technology Committee, House of Representatives, resolved that Tokyo University not handle the development of large rockets measuring 1.4 m in diameter (the size of the present Mu rocket) or more. This resolution not only badly disgraced Tokyo University, but left grudges of great proportions which largely account for the continuing feud between the Ministry of Education and the Science and Technology Agency or between the Institute of Space and Astronautical Science and NASDA.

The other reason is that Japan is subject to many U.S. regulations, including the prohibition of launching third-nation satellites because of NASDA's dependence on imported American technology for the development of rockets and satellites. Specifically, there are scruples to avoid the eventuality that the Institute of Space and Astronautical Science, which conducts space development by purely Japanese technology, might come under U.S. control if it were forcibly unified with NASDA while the latter's dependence on U.S. technology continued.

The Space Development Committee in December 1979 pronounced as an informal understanding the policy to "place the development and launching of rockets solely in the hands of NASDA, as a principle, in FY 1988 when Tokyo University's development program for the Mu 3S rocket series, which are its main rockets, is completed as scheduled."

But this policy is, in effect, being shelved at present. The Institute of Space and Astronautical Science, while keeping the framework of the 1.4-m diameter in mind, is attempting a breakthrough by gradual size increase from Mu 3S2 to Mu 3S3, and is also planning to use the U.S. Space Shuttle for its scientific research satellites too large to be launched by Mu 3S rockets, including the magnetosphere observation satellite (GEOTAIL) scheduled to be launched in 1991. The Institute of Space and Astronautical Science claims that "a NASDA satellite costs more than Y10 billion, but most of our large satellites are covered by the international joint observation plan and, therefore, cost almost nothing if the shuttle is used."

But many concerned people believe that this position is merely ostensible and "in truth, they do not want to use NASDA's rockets at all."

The Space Development Committee started basic research for the Japanese version of the Space Shuttle in FY 1986. It is planning first to develop a minishuttle for two or three people to be completed after the turn of the century. Here, too, rivalry has already become apparent between the "Hines project" of the Institute of Space and Astronautical Science and the "space round-trip transport plane project" jointly of NASDA and the National Aerospace Laboratory.

Space Development Committee Is Too Weak

The rise of user agencies, such as the Ministry of Posts and Telecommunications, the Ministry of International Trade and Industry, and the Defense Agency, is likely to face an even worse problem than the struggle for leadership between the Ministry of Education and the Science and Technology Agency. This is due to the fact that with the start of the American Space Shuttle and other achievements, the advent of the era of the commercial use of space has become imminent. The shuttle, which can take three communications and other satellites into orbits around the earth at a time, costs less to launch than a rocket. It also makes the manufacture of pharmaceuticals, semiconductors, and new materials possible under conditions unavailable on the ground, taking advantage of the severe limits of space environments such as weightlessness and vacuum. That is why space is said to be the stage for the industrial revolution of the 21st century.

The Ministry of Posts and Telecommunications has actively supported NASDA in accordance with the national policy "to use mainly Japanese technology in this country's space development," and played a leading part in developing the communications satellite Sakura used mainly by Nippon Telegraph and Telephone Co. (NTT) and NHK's broadcasting satellite Yuri.

But recently this ministry suddenly gave up pursuit of the policy of space development using exclusively Japanese technology. It hastily approved the satellite communications business of two private satellite communications companies in accordance with the government decision to buy American communications satellites as a measure to end the trade friction with the United States. This does not mean that the ministry has altogether dropped the policy to develop using Japanese technology. On the contrary, it clearly wants to expand its jurisdiction in the development and utilization of space by increasing the number of its satellite launchings through combined use of Japanese and imported technology.

The Ministry of International Trade and Industry is also very eager for the development and utilization of space. It is not only engaged in the development of an earth resource satellite jointly with the Science and Technology Agency and is participating with private industries in experiments to manufacture new materials jointly with West Germany, taking advantage of space environments, but it has also started the development of an unmanned material testing satellite (Free Flyer) with the cooperation of the Institute of Space and Astronautical Science.

Properly, the Space Development Committee, which is the supreme organ for space development, should maintain integrated control over the conduct of space development projects by different organs under a unified national plan. As it is, however, the committee has decisive weaknesses, namely: 1) It is merely an advisory organ to state opinions to the prime minister, 2) it can only plan, deliberate, and decide on matters concerning space development and pertaining to different government agencies, and "utilization" is not included, and 3) it has no right to decide on the development and utilization of space by private circles. The lack of organization in the Japanese setup for the development and utilization of space may well be attributed to the status of the Space Development Committee, which is legally and structurally too weak.

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AEROSPACE SCIENCES

TRANSFER, EVALUATION OF AIRCRAFT INDUSTRY TECHNOLOGIES

Tokyo KOKU GIJUTSU in Japanese Jun 86 pp 9-14

[Article by editorial staff]

[Text] The following outline--printed with permission of the Japan Aerospace Industrial Association--gives the results of the survey taken by the association on connections between aircraft industry technology and other industrial technologies. It includes mutual transfer and evaluation of technologies and effects of aircraft technology on other technologies in order to study the ideal position of the aircraft industry in the fabric of society. In the association's view, unobstructed information exchange and technology transfer with other industries are necessary to advance Japanese aircraft industry technology.

The survey concerned five items: 1) consolidation of aircraft industry technology; 2) grasp of relationship with other industrial technology; 3) inquiry into the realities of technology transfer and exchanges with other industries; 4) outlook of effects of aircraft technology development on other technology; and 5) study of the role of the aircraft industry in the fabric of society. In the report, these survey results were consolidated into five chapters: 1. System of Aircraft Industry Technology; 2. Effects of Technology Transfer on Other Industries and Prospects; 3. Factors, Results of Accelerating Technology Transfer; 4. Measures To Accelerate Technology Transfer, Evaluation of Effects on Other Industries; and 5. Summary (attached as a data section is a matrix classification table on mutual technology transfer involving aircraft industry and 17 other industries--automobile, ship, submersibles, rolling stock, consumer goods, robot, materials, chemical products, electronic equipment, space, guided missiles, motors, atomic energy, electricity, bridges, wind force, and iron/steel.

1. Aircraft Industry Technologies and Trends

A. System of Aircraft Industry Technologies

The association studied the system of aircraft industry technologies from the viewpoint that the classification of basic technology and the definition of their details must first be clarified for the purpose of inquiring into the relations between the aircraft industry technology, which is the nucleus, and other industrial technologies. The classification indicated in Table 1 was adopted.

Table 1. Classification of Aircraft Industry Technologies

Area of technology	Explanation of details	Technologies either currently in use, or being improved or under development	Technologies expected to be in use or being improved or under development by 2000
1. System integration and managing techniques	Managing techniques and means to ensure the quality of the overall system through planning, development, design, manufacture, operation, etc., and execute duties efficiently. (Example 1): Reliability and safety managing techniques, development managing techniques (EMS, etc.), production managing and quality managing techniques, etc. (Example 2): Computer using techniques, CAD/CAM, CAE, system integrating techniques, simulation techniques, etc.	Development managing techniques (EMS), reliability/safety managing techniques, form managing techniques, rear support techniques, ASIP, data deciding CAD, two-dimensional CAD/CAM, CAE and flight simulator for development use.	Integrated CAD/CAM, CAT, antifault system designing techniques and large-scale simulation techniques.
2. Operation techniques	Navigation, air traffic control, maintenance/supply, training and other system techniques aimed to improve safety and economy in aircraft operation, ensure punctuality and adaptability, reduce health costs and decrease pilots' workload.	Navigation and control system (ATCRBS, VOR, ILS, DME, INS, RNAV, FMS, etc.,), AIDS, BITE, ATE, AIS, product support and flight simulator for training use.	Supervisory secondary radar (SSR)·mode S, MLS, traffic warning·collision avoiding system (TCAS), obstacle monitoring system (using laser radar), windy/clear air turbulence/slip stream eddy avoiding system, satellite navigation (GPS, etc.), RNAV (four-dimensional), advanced FMS (using artificial intelligence, etc.), integrated cockpit, air control automatic system and automatic meteorological observation·communication system.
3. Aerodynamic technology	Aerodynamic technology, such as ① computing/analyzing technology, ② designing methods, and ③ form elements aimed to improve the maneuvering capacities of aircraft, reduce resistance, improve engine capacities and reduce noise.	Computer-using aerodynamic analysis (nonviscous flow), transonic wing aerodynamic analysis (nonviscous flow) (including reverse solution for deciding optimum shape), mechanical high-lift apparatus and low-resistance wing shape.	Computer-using aerodynamic analysis (viscous flow), transonic entire-plane aerodynamic analysis (viscous flow) (including reverse solution for deciding optimum shape), boundary layer control (including laminar flow), wings with optimum flight form, aerodynamic noise reduction (airframe and rotor), advanced rotor, powered high lift device and device to reduce induced drag (wings with small tips, etc.).
4. Flight control technology	Design, manufacture, and installing technologies for automatic flight control aimed to improve the maneuverability and safety·controllability of aircraft, optimize flight and achieve energy conservation and systems to control flight characteristics including active control	Automatic controls, SAS, CAS, FBW, automatic landing gear and redundancy control techniques.	Active flight control technology (ATC) (RSS, MLC, GLA, FMC, etc.), integrated flight control, FBL, thrust deflecting formula, harmonic vibration control technology, sensor system technology for flight control (skewed sensor, automatic center of gravity measuring system, etc.).

[continued]

[Continuation of Table 1. Classification of Aircraft Industry Technologies]

Area of technology	Explanation of details	Technologies either currently in use, or being improved or under development	Technologies expected to be in use or being improved or under development by 2000
5. Structure and strength technology	Such technology as ① computing/analyzing technology, ② structural forms, and ③ designing methods (including damage allowance design) aimed to reduce the weight of airframes and engines, achieve high reliability and reduce vibration.	Computer-using large structure analysis (linear), honeycomb adhered structure, metal adhered structure, and damage allowance designing method (metals).	Computer-using large structure analysis (nonlinear), collision·impact load analyzing method, damage allowance designing method (composite materials), optimum structure designing techniques (including aeroelastic tailoring) and strength·destruction phenomenon simulation techniques.
6. Materials technology	Technology to develop, use, and evaluate such materials as ① metals (iron, light alloys, heat-resistant alloys, etc.), ② nonmetals (plastics, rubber, ceramics, adhesives, paints, etc.), and ③ composite materials (FRP/PMC, FRM/MMC, etc.) aimed at high strength·weight reduction and resistance to heat and environment.	Highly purified new high-tensile aluminum alloys, alloys reinforced by oxide dispersion, high-strength high-toughness alloys, single crystal alloys, CFRP, and AFRP.	Super-plastic aluminum alloys, high-toughness ceramics, quenched powder aluminum alloys, ceramics composite materials, quenched titanium alloys, intermetallic compounds, heat-resistant eutectic alloys, highly conductive composite materials, heat-resistant FRP/PMC and FRM/MMC.
7. Processing and producing technology	Such technology aimed at the increase of production efficiency, cost curtailment, and the ensurance of processing accuracy as plasticizing, machining, welding (including brazing), heat treatment, precision casting, powder metallurgy, HIP, CIP, special processing (leather processing, etc.), chemical treatment, surface treatment, adhesion, assembly, outfitting, and processing systems (FMS, etc.).	Super plasticizing (titanium alloys), carbon fiber production, CFRP·AFRP molding, ceramics molding, electronic beam welding, diffused junction (titanium alloys), skin mirror surfacing and precision casting (DS/SC).	Super plasticizing (aluminum alloys), complex processing of lightweight integral structures including super plasticizing + diffused junction, liquid phase diffused junction, laser beam machining, HIP, and other near-net shape processing, anti-corrosive techniques, FMS, and low-cost molding of composite materials.
8. Propulsive system technologies	Technologies concerning combustion·fuel system, thrust control, cooling, lubrication, propellers·rotors, and power transmission.	Low-speed propeller technology, medium-size high bypass ratio turbofan engines, wide cord fans, electronic engine control, turbine blade cooling techniques, lightweight, high-reliability gear for props.	Unsteady characteristics (engine control), high-speed propeller technology, variable pitch fan technology, core engine technology, cooling turbines and low-emission combustors.

[continued]

[Continuation of Table 1. Classification of Aircraft Industry Technologies]

Area of technology	Explanation of details	Technologies either currently in use, or being improved or under development	Technologies expected to be in use or being improved or under development by 2000
9. Electric·electronic equipment technology	Techniques of designing, manufacturing, and installing electronic instruments for airborne communication, navigation, automatic control, display, etc., (including computers) as well as power source, power distribution, and other equipment.	Communications equipment (HF, VHF, and UHF), navigational equipment (ADF, VOR, ILS, DME, TACAN, RADAR, LORAN, OMEGA, INS, HUD, and DADC), general instruments, automatic flight control, automatic landing system, power equipment (IDG, TR, INVERTER), and lighting equipment.	Computer technologies (high-performance computers, high-reliability software, voice control, and expert system), optical fiber gyro, nuclear magnetic resonance gyro, collision preventing system turbulence slip stream detector, all-weather automatic landing system, integrated display system, system function monitoring system, multiplexed intercommunication, power equipment (VSCF, high-voltage power source, SOSTEL, IEG, and automatic distributor).
10. General equipment and parts technology	Techniques of designing, manufacturing, and installing pressurizing·air conditioning, hydraulic, landing gear, ice preventing/removing, cabin equipment, and other general equipment not included in above electric and electronic equipment.	Cabin equipment (seats, toilets, kitchen units, containers, galleys, carts, water tanks, lifesaving appliances, and interior materials), landing gear (antiskids, tires, and brakes), hydraulic equipment (electric, hydraulic servo valves, and high-pressure hydraulic equipment), ice preventing/removing (boots, electric, and high-temperature pneumatic type), and air conditioning equipment (vapor cycle and air cycle).	Super lightweight seats, new interior materials, superhigh-pressure hydraulic equipment, actuators (optical actuator, electric actuator for primary control and direct drive actuator), high-efficiency, high-reliability braking system (brake by wire), air conditioning system (electronically braked type, electric compressor type, lightweight heat exchanger), ice preventing/removing system (heat pipe type, flow control type, electromagnetic control type, and ice-preventing paints).
11. Testing and inspection technology	Techniques of wind tunnel test, structure-related tests, propulsive system test, environment test, electronic system test, flight simulation test, flight test, nondestructive inspection, material test, measurement·data processing technologies (including CAT), and so forth.	High Reynold's number two-dimensional transonic wind tunnel, engine ground operating equipment (muffler), flight simulator, flight by flight fatigue test, computer-controlled multipoint-excited vibration test, acoustic fatigue test equipment and ATE technologies.	High Reynold's number three-dimensional transonic wind tunnel, low-temperature wind tunnel, anechoic wind tunnel, numerical experiment simulator, engine aerial performance test equipment, structure test equipment (including environment load equipment), instrument environmental test equipment (weather tunnel), nondestructive inspection method and artificial intelligence type testers.

B. Trends of Individual Techniques

(1) System Integrating and Managing Techniques

Technical work management by EMS (engineering management system) is now beginning to be practiced as a technique to manage large-scale development. This is aimed at making new products most economically by conforming performance, specifications, and other duty targets to budget and schedule targets in the conduct of large-scale development of the products. It is to incorporate such methods as reliability and safety management techniques, form management techniques, and rear support engineering; in the future, the efficiency of development management conforming to targets will be stepped up as the use of computers is expanded.

With advances in equipment, such as small electric actuators, the full-electric aircraft system, namely, all airframe systems including the engine system electrified with the object of increased efficiency and energy conservation will become practical.

(2) Operation Technology

Relative to Navigation and Control System: ICAO is studying the use of an SSR (secondary surveillance radar) mode S with high position finding accuracy by the individual call formula and bidirectional high-speed data-link function along with the present SSR. SSR, which is the source of information for air traffic control, involves the fear of ATC causing saturation of speech communication in a high-density flight area and the SSR mode S is scheduled to be put into practical use in 1988 or thereabouts.

ILS used as a landing guidance system has problems including the necessity of level ground electric wave reflection from buildings and nearby aircraft. So, there is a plan underway to introduce MLS (Microwave Landing System), a system of the next generation, as a drastic countermeasure.

TCAS (Traffic Alert and Collision Avoidance System) gives a warning or evasive action instruction to the pilot when there is the danger of collision. It will soon be made practical, mainly in the United States.

Further, if GPS (Global Positioning System), which is a new satellite navigation system, becomes practical, accurate three-dimensional positioning and speed and time decision will be possible worldwide and can be expected to contribute to the drastic improvement of navigational accuracy and be effectively used for such purposes as RNAV.

As air control automatic systems, efforts are now being made to automate the screening and processing of flight plans and automate radar information processing, abnormal approach warning programs, etc., but, in the future, the drastic automation of control work processing by, among other things, the modernization and reliability enhancement of the air control computer display system will be made possible basically by developing computer and data link techniques.

Automatically detecting adverse meteorological phenomena extremely dangerous to aircraft and promptly and extensively communicating the meteorological information to both pilots and controllers by an automatic meteorological observation and communication system is effective for reducing air accidents and navigation delays due to bad weather. For this purpose, it is necessary to develop a meteorological processor for air traffic control centers, provide airports with automatic meteorological observation systems and develop an aeronautical meteorological radar network.

Integrated Cockpit: The workload of pilots now tends to increase not only because of the increase of aircraft instruments due to the sophistication of aircraft but also the excessive density of flights and the necessity of quiet navigation and fuel conservation. To reduce this workload but assure safe navigation, efforts are being made to integrate cockpit instruments. The workload of pilots is being drastically reduced as the result of the development of the color CRT and computer automation. In the past, large aircraft have required three cockpit personnel: a pilot, copilot, and navigator, but now only two, pilot and copilot are beginning to suffice.

In the future, such new techniques as HUD (head up display), HDD (head down display), and flat display will be further improved and, with the adoption of the FBW steering formula, steering by a small, simple stick, rather than by the control stick of today, will become possible. Also, with the adoption of a speech synthesis/recognition device and artificial intelligence technology, the pilot's work of information acquisition, assessment, and operation will be greatly automated, and the pilot will work mainly at monitoring. As the result, the cockpit will lose its past image and, instead, assume the image of the control room at a large industrial plant. Technically, navigation by a single crew member will be possible.

Maintenance: Engine and other systems will be provided with sensors, thus continuously detecting and recording conditions in flight and displaying abnormal data real-time in the cockpit. AIDS (aircraft integrated data system) now used to monitor tendencies in functional deterioration or determine disorders through off-line data processing by a ground computer will, in the future, enable a considerable part of data processing to be performed real-time aboard the plane as the computer becomes more sophisticated.

Already, many electronic devices incorporate airborne BITE (built-in test equipment), which is built-in equipment capable of checking by a test switch to see whether each subsystem is functioning properly and locating and identifying internal disorders to a certain degree.

AIS (avionic intermediate shop) is a system to diagnose and analyze efficiently at the maintenance shop stage faulty units having been replaced after the BITE detection of their disorders. Here, ATE (automatic test equipment), which can quickly determine functions and detect disorders, is useful.

Product Support: This is the manufacturer's support activities, such as technical support and the supply of parts, for the user's navigation and maintenance management (servicing) and is deemed to be as important as the design quality and manufacture quality of the aircraft itself.

Flight Simulator for Training: With the recent progress of electronic technology, techniques concerning field-of-vision apparatus, particularly the CGI (computer generated image) formula, have developed remarkably, making possible the faithful simulation of flights and the appropriate conduct of training instruction and contributing immensely toward not only efficient training but also energy conservation as a means equivalent to real-plane flight training.

(3) Aerodynamic Technology

The computation of aerodynamic characteristics (pressure distribution, etc.) for fairly complex shapes has become possible as an aerodynamic computing and analyzing technique using the computer. Furthermore, rapid and highly precise aerodynamic analyses will be made possible in the near future by the introduction of a numerical simulator system to which a supercomputer is central. The regular practical utilization of the power-type high lift system and the induced drag reducers (tip winglet, etc.), which are now being developed, also seems to be imminent. The helicopter rotor will be greatly improved hereafter with the progress of the techniques to analyze the aerodynamic characteristics of the rotor. As for noise, advancement of techniques to elucidate and analyze the phenomenon of aerodynamic noise generation will go a long way toward reducing noise.

(4) Flight Control Technology

So far, it has been customary to connect flight control devices by mechanical linkages, such as cables and rods. With the progress of techniques concerning small airborne computers and the improvement of capacities of various sensors, the FBW (fly by wire) system to convert pilot input into electric signals and transmit the signals by electric wiring via operation at the controls is beginning to be practically used. Moreover, ACT (active control technology) which, using this FBW technique, makes active computer-control of air controls by information from sensors, controls the movements of the airframe or the structure by different modes and thereby improves maneuvering capacities, reduces weight, conserves energy and improves riding comfort, is about to become practical.

(5) Structural and Strength Technologies

The structural and strength technologies used to develop aircraft are, along with the remarkable improvement of computers and technologies to use them and the development of new materials, continuing to advance with regard to computing and analyzing techniques, structural modes and design methods, and proving to be exceedingly effective in such respects as weight reduction, the achievement of high reliability, and the decrease of vibration.

(6) Material Technology

Materials aimed at high strength, high rigidity, heat resistance, and resistance to environment are making remarkable progress and expected to continue to develop toward the 21st century. They are, for example, the aluminum/lithium alloy with a specific gravity smaller than that of the conventional

high tensile aluminum alloy and a high modulus of elasticity which has been developed for the purpose of improving the performance, efficiency, and reliability of aircraft and their conformity to environments and the advanced composite materials produced by combining carbon, aramid, and other fibers and epoxy and other resin matrixes.

(7) Processing and Producing Technologies

In the manufacture of aircraft, weight reduction and high accuracy are in strong demand. To meet this demand, processing and producing techniques now being developed and adopted comprise advanced techniques including super-plastic processing, welding/joining techniques and near net shape molding. Meanwhile, there is growing demand for reduced production costs and techniques aimed at the improvement of production efficiency and the conservation of resources and energy are being developed and advanced.

(8) Propulsive System Technology

The types of engines selected for commercial planes are high bypass, low fuel consumption engines for large planes used for low-cost mass transportation and small bypass ratio high-speed low fuel consumption engines for business planes used for long-range transportation. ATP (advanced turboprop) planes are noted as long-range cargo planes to which fuel consumption is important and short-range medium passenger planes and the R&D of ATP engines will be stepped up in the future. It seems that with a view to optimum control automatic navigation, engine control will be digital-computerized and FADEC (full authority digital electronic control: full-electronic engine control), and the optical fiber will be used increasingly.

Inasmuch as the advancement of technologies and the diversification of operation constitute progress, in developing an engine system for practical use it is important to form an optimum basic plan after careful checks and studies including simulation.

(9) Electric-Electronic Equipment Technologies

The advance of avionics-related electronics is said to be fast and unpredictable, but the individual technical items listed in the column of "Technologies expected to be in use or being improved or under development by 2000," in Table 1 are what is presently regarded as important items of development and probably can only be accomplished by the use of digital and optical techniques and new materials plus the advance of high-density packaging techniques. Japanese companies are rather reluctant to develop some of these individual technical items because their market for aircraft use in this country is still small but, as far as optics, for example, is concerned, Japanese technology ranks among the best in the world and thought to be, indeed, promising.

(10) General Equipment and Parts Technologies

General equipment and parts for Japanese aircraft are largely products made by licensed foreign technologies and incorporating improvements made on Japan's own. As the result, parts with high reliability and safety are available for the controls, landing, hydraulic, air conditioning, anti-icing, and interior equipment of smaller to larger aircraft. These are at the European and American technical levels and many of these items are exported.

Aircraft of today must not only fly safely but also have ease of cargo handling, and enhanced reliability and durability. At the same time, cost reduction is severely demanded of them.

(11) Testing and Inspecting Technologies

In the recent development of aircraft, tests and inspection have become more important than ever and quantitatively increased so as to be able to meet the new social requirements of energy conservation, resources conservation, and harmony with the environment.

Under this demand, Japan is gradually adopting new testing and inspecting equipment, such as composite material structural test equipment and noise testing equipment. Yet, it lags far behind the European countries and America in introducing this equipment. Installation and replacement of equipment will progress in the future. It is expected that the introduction will be made successively, beginning with equipment necessary at the stage of advanced research--notably, the high Reynold's number three-dimensional wind tunnel and the numerical test simulator.

2. Effects of Mutual Technology Transfer Among Industries

Chapters 2 to 5 of the report, are summarized below.

Versatile technology transfer has taken place between aircraft and non-aircraft industries, each expediting technical development in the other and contributing greatly to its activation.

In transferring a technique, both the sender and the receiver evaluate it. To step up technology transfer, the results of the transfer and the effects useful to both sides must be gathered and assessed to prevent failures.

The aircraft industry is an intellect-intensive industry with very high added value and immense technical effects on non-aircraft industries and, as such, indispensable to the resources-poor Japan which must survive as a technical nation. Besides, it is a strategic industry with a vital role in the industrial fabric of the nation. The characteristics of the technology of the aircraft industry include the following:

(1) Up-To-Date Technology

Rigorous requirements of weight reduction, safety, and reliability against gravitational force, and requirements of latest technology and low environmental pollution have been demanded of aircraft. To meet these requirements, most advanced technologies have continued to be developed.

(2) High System

Aircraft are composed of airframes, engines, electronic and electric equipment, precision machines, machine parts, hydraulics, chemistry, and materials including a wide range of products from related science, technology, and industries and must satisfy high technical requirements in all these areas. So, the aircraft industry leads as a system technology in that it extracts and integrates most advanced techniques for different components and, in so doing, raises them to higher levels.

(3) High Management Techniques

The management techniques necessary to integrate technologies for the aircraft itself, which is a complex system, and the various management techniques for sale and service to customers are advanced and efficient.

(4) High Added Value Rate

The aircraft industry is an assembly industry with a particularly high added value and can be deemed as an industry befitting Japan as a resources-poor nation.

(5) Related Industries Covering Wide Range

The aircraft industry comprises the airframe and engine manufacture, which forms the apex, electronic equipment, hydraulic equipment, materials and members, machine parts, precision machine tools, and other related industries. To the electronics industry and the new materials industry in particular, new product areas created by the aircraft industry are important.

(6) Intellectual Labor-Intensive Industry

In Japan which has a work force that is superior, highly motivated and well educated, the aircraft industry is outstanding as an industrial type to create work motivation.

In the future, the Japanese aircraft industry is expected to qualitatively contribute to the economic society of the country by bringing its knowledge intensiveness and technical leadership into play as a nucleus of promising composite system industries. Conversely, the likely transfer of technology from non-aircraft industries is important to the aircraft industry. The aircraft industry should make sustained efforts to adopt useful technology by actively inquiring into the technology of non-aircraft industries (see Table 2). (Source: Nippon Koku Uchu Kogyo-kai Shiryo of June 1985.)

Table 2. Prospective Transfer of Technology Between Aircraft and Other Industries

Aircraft industry technology	Transfer to other industries (number of cases)	Transfer from other industries (number of cases)
System integrating and managing technology	52	12
Operation technologies	7	12
Aerodynamic technologies	13	3
Flight control technologies	3	3
Structural and strength technologies	32	10
Material technologies	61	34
Processing and producing technologies	41	16
Propulsive system technologies	10	17
Electric-electronic equipment technologies	49	47
General equipment and parts technologies	18	33
Testing and inspecting technologies	46	24
Others	7	16
Total	339	226[sic]

20,108/9365
CSO: 4306/2586

AEROSPACE SCIENCES

INNOVATIVE AIRCRAFT R&D PLAN FOR 21ST CENTURY VIEWED

Goal of Improved Technology

Tokyo KOGIKEN NYUSU in Japanese Jun 86 pp 1-2

[Article by the Energy-Saving Technology Research Team]

[Text] Setting a goal to improve Japanese aviation technology to the top level in the world by the beginning of the 21st century, the Aviation and Space Technology Institute is presently considering "an innovative aircraft R&D plan for the 21st century" as its most important new subject for FY 1987.

This plan is to establish new energy-saving technology to reduce present fuel consumption of the newest airplanes by more than 50 percent. Actual flights will be used by manufacturing a demonstrator, and then making preparations for practical application. This R&D project is scheduled to begin in 1987 and terminate by 1996. Figure 1 shows one of the examples for the demonstrator. The technologies applied to the demonstrator will be as follows (see Figure 2).

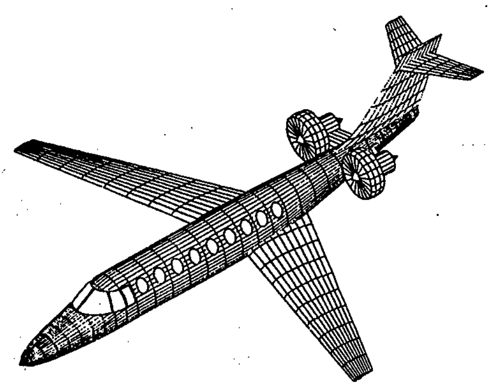

Figure 1. Demonstrator Model

(1) Drastic reduction of air resistance by technologies related to laminated flow control and forward airfoil.

(2) Application of new materials (heat plasticity plastic composite materials), a lightweight body with an integrated formed structure with no joints and no rivets.

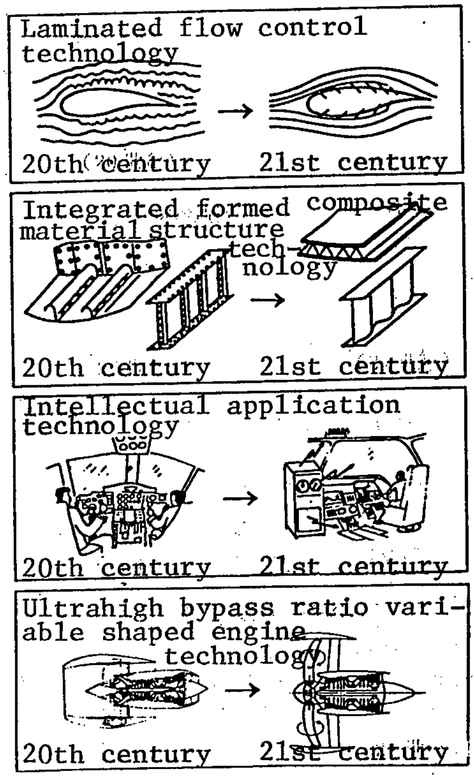

Figure 2. Element Technologies Applied to Demonstrator

(3) Energy-saving, reducing labor, and improving safety by intellectual control technologies with "fly-by-light."

(4) Substantial reduction of fuel consumption using ultrahigh bypass ratio variable shaped engines.

Figure 3 outlines this plan.

Nowadays, air transportation is nearly a monopoly in the field of long-distance passenger traffic. This has been realized mainly by continuous technological innovations, such as high speed (jet plane), energy-saving (fan jet and new airfoil), large sizes with wider bodies, and reduction of labor by control technologies.

Presently, among advanced countries in Europe and America, technological innovation is actively pursued. In the case of the YXX project, which is scheduled to be studied jointly by Japan and the Boeing Co. in the United States, the adoption of an ATP engine, which will bring significant energy savings, will be investigated. If Japan neglects positive R&D, we will be left behind in the march of worldwide technological innovation.

A jumbo jet which flies between Narita (Tokyo) and Los Angeles loads 120 tons of fuel for 40 tons of passengers. It is no exaggeration to say that a passenger airplane, especially a long-distance airplane, carries fuel and spends money

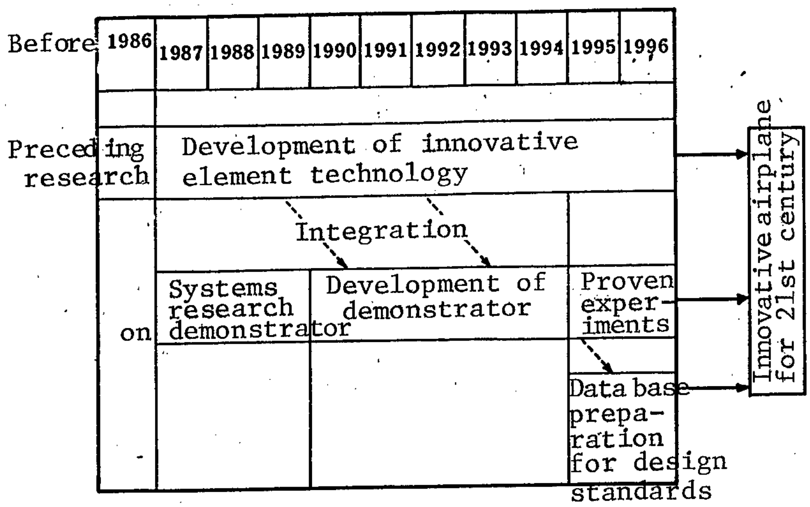

Figure 3. Schedule of R&D

rather than transports passengers. If the amount of fuel can be reduced by half, it will be possible to increase substantially the number of passengers. Energy-saving technology which reduces fuel will be a tremendous advantage even if fuel does not cost anything. In this sense, energy-saving technology has been a main consideration in aviation technology even before the oil crisis. This technology is indispensable. In addition, as seen from sheer wind load reduction technology, which makes safer and more comfortable flights possible and also reduces vibrations in heavy winds, there are several energy-saving techniques with various advantages in the fields of safety, accommodation to environments, and airline services besides the reduction of fuel. Furthermore, energy-saving technology expedites the commission of STOL (short take-off and landing) and a commuter, which have been unprofitable in the past, by reducing operating costs through low fuel consumption and ultra-light weight. Ultra-long distance transportation becomes possible with the same amount of fuel. For instance, it becomes possible to go anywhere in the world without changing airplanes and without extra fuel. A wider body becomes possible with the same amount of fuel. This brings a more comfortable trip to a passenger, who can sit in a wider seat. As described so far, these technologies have various possibilities.

The purpose and object of this plan is to increase the level of Japanese technology in the area of high subsonic airplanes, which can be considered the leading edge of aviation transportation for the next several decades. It also aims at realization of a transport plane, developed independently by Japan, flying over the world by the beginning of the 21st century.

Wind Tunnel Device

Tokyo KOGIKEN NYUSU in Japanese Jun 86 p 3

[Article by R. Sakakibara, Aerodynamics Second Division: "2m x 2m Transonic Wind Tunnel Wall Pressure Measurement Device"]

[Text] A wind tunnel is indispensable as an experimental facility. It reproduces the state of air flow for a real airplane. When an airplane has performed its important duties in the transportation business, and comparative advantages and disadvantages of its economical efficiency affect the fate of a transport plane newly developed, it becomes necessary to exactly estimate a real aircraft at the development stage. Because of this, extremely high accuracy is demanded for wind tunnel tests. However, various factors which disturb faithful simulation exist between an experiment with an actual airplane and a wind tunnel test. This is an obstacle to improving accuracy. Especially, in the case of a transonic wind tunnel test, how to modify the effect of interference from the wind tunnel's wall is important. It is necessary to effectively clear up the pressure distribution of the walls near the place where measurements are carried out. Since the measurement area of pressure distribution which is inevitable for the modification of wind tunnel wall interference covers most of the portion where the measurements take place, it is necessary to have large-scale repair work done on an existing wind tunnel. This requires great expense. Given this, at this time, a system to easily measure the pressure distribution of the walls which cover almost all of the measuring portion of 2m x 2m transonic wind tunnel was developed by this institute. That is, we noted the fact that an orifice placed on the surface of the length, in the direction of the air flow, and a thin plate shaped body called a static pressure rail on the wall of a wind tunnel, can measure static pressure around the wind tunnel wall. By utilizing this phenomenon as a probe to traverse the wind tunnel wall, the pressure distribution measurement device enables us to conduct pressure measurements like "a line," and a plane is also developed. This device is able to measure the pressure distribution of the wall not only for the wind tunnel itself, but also the measurement system without any modifications.

The measurement area of both prototype devices for a side wall and a floor covers 46 points in the direction or air flow and 17 points in the transverse direction in the number of pressure measurement points (since the rail is able to traverse freely in the transverse direction, measurements are possible from any arbitrary position). Its dimensions are 2.6 meters in the direction of air flow and 1.8 meters in the transverse direction. An example of the results of wall pressure distribution measured by the ONERA-M5 Model is shown in Figure 2. It is expected that this device will provide useful data for our study about the modification of the 3-dimensional wall interference effect of the 2m x 2m transonic wind tunnel in the institute.

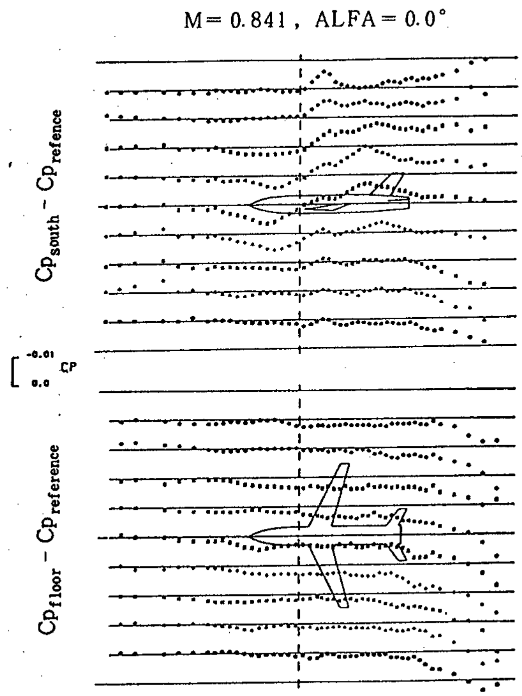

Figure 2. Example of the Measurement Results of Wall Pressure Distribution (Side Wall and Floor) in the Presence of ONERA-M5 Model by the New Device

Use of Composite Materials

Tokyo KOGIKEN NYUSU in Japanese Jun 86 pp 4-5

[Article by T. Shimogawara, Airframe Second Division, "Introduction of Small-Sized Environment Chamber for Composite Materials Fatigue Tests"]

[Text] In order to save energy, the increase of payloads, and the improvement of flight performance by drastically reducing the weight of the airframe structure of an airplane, development of a composite materials structure centering around carbon fiber composite materials has been actively pursued. In some cases, a reduction by 15 to 35 percent in the weight of the composite materials structure is achieved when compared to a metal structure. In the future, we will look for the realization of a 50 percent reduction in weight, a reduction in cost by integrated formation of large-sized structures, an improvement in safety by increasing fatigue strength, and a reclaimed structure to restore the original state with the application of heat plasticity plastics even if it causes damage. As for the structure of the mass production level, the composite materials structure has started to be used for the primary structure of a main wing which sustains main loads in warplanes. It is gradually reaching the stage of full-scale practical application. On the other hand, its application is presently limited to a secondary structure such as a movable wing or fairing

which does not sustain main loads in civil airplanes. However, it is scheduled to adopt a composite materials structure for the vertical and horizontal tail assemblies of the A-320 airbus now in development. In the YXX (B-7J7) project, which is jointly studied by JADC (Japan Airplane Development Council) and the Boeing Co. in the United States, a composite materials structure is expected to be utilized for the primary structure on a large scale. In addition, under the institute's innovative airplane development plan for the 21st century, one idea is to have a composite materials airframe which uses a large volume of heat plasticity plastics, although it is for an experimental airplane.

As described above, the introduction of a composite materials structure into a civil airplane lags behind that for a warplane. The reason for this situation is that in the case of a civil airplane, it is necessary to assure satisfactory reliability and safety of the structure for a long period of time. Particularly, when a composite materials structure is going to be used for a long time, the absorption of water and environmental fatigue are serious problems.

Repeated loads must be studied in the case of conventional metal structures. However, in the case of a composite material structure, the material absorbs moisture contained in the air. This phenomenon is sometimes combined with temperature cycling loads during actual usage. As a result, fatigue strength is drastically lessened. Accordingly, at the design stage, very careful attention has to be paid to environmental fatigue of a composite materials structure.

In order to conduct an environmental fatigue test combined with repeated loads, a small-sized environment chamber for the composite material fatigue test has been introduced. This device, attached to a conventional electric oil pressure servo-type fatigue testing machine, can generate a constant environment and/or environment cycling with the conditions of temperature and humidity. Specifications are shown in the table. The test environment on the inside of the chamber is designed to be controlled by a personal computer, available on the market. During a power failure, suspension of water supply, excessive increases of temperature, or other troubles, the safety devices installed in both the environment chamber and the fatigue testing machine go into action. Under a combination of the environment chamber and a fatigue testing machine, the fundamental nature of environmental fatigue strength, including the effect of moisture, will be studied for a composite material test piece and a composite material structural element. At the same time, basic data which is useful for environmental fatigue design of composite material primary structure for civil airplanes should be obtained. As the pilot device of the composite material structure testing facilities, planned for the institute, it will be utilized for future problems of construction of the environment chamber or the environment fatigue testing device, by operating these under various conditions.

Table. Main Specifications of Small-Size Environment Chamber for Composite Material Fatigue Tests

Item	Specifications
Dimensions of environment chamber (inner)	Width: 300 mm Depth: 400 mm Height: 540 mm
Temperature range	- 60 to 150°C
Temperature fluctuations	Within ±1°C (steady state)
Temperature distribution	Within ±3°C (-60 to 150°C)
Temperature increase rate	Within 60 minutes (RT to 150°C)
Temperature decrease rate	Within 120 minutes (RT ~ -60°C), within 15 minutes (liquid nitrogen in use)
Humidity range	30 to 95 percent RH (25-95°C)
Humidity fluctuations	Within 7 percent RH (steady state)

Star Sensor Flight Model

Tokyo KOGIKEN NYUSU in Japanese Jun 86 pp 5-6

[Article by Y. Sakurai, Measurements Division: "Outline of Flight Model of Star Sensor for Loading Experiment"]

[Text] As the payload (satellite) for the first H-1 rocket two-stage experimental launch, scheduled during the summer of 1986, the magnetic bearing flywheel experimental device (KOGIKEN NYUSU 1986 April No 324) is planned to be installed. The star sensor will be used as one of the positioning monitors for this experimental device. This is the first time for Japan to install this kind of star sensor. Since the flight model of the star sensor for loading experiments has been newly developed, it is introduced in this article. This sensor uses a two-dimensional CCD (Charge Coupled Device) solid image element as a detector. In order to increase sensitivity, electronic cooling of the CCD is carried out by the Peltier element. Because of this, it is possible to detect about up to a star of the sixth magnitude. Table 2 shows the principal specifications of the star sensor. In this table, resolution is the angle corresponding to one page of the CCD. The detecting accuracy of the position (angle) of a star can be expected to be up to 1/1000 by carrying out calculations of the centroid in the case of a bright star.

Table 2. Main Specifications of Star Sensor

Item	Contents
Detector	2-dimensional CCD (TCD203C)
Number of pixels (page)	400 (horizontal) x 500 (vertical)
Size of a page	22 (H) x 13 (V) μm
Optical system	f = 55 mm, F = 1.2
Field of view	7.16 (H) x 5.49 (V) degrees
Resolution	0.0299 (H) x 0.0135 (V) degrees
Sensitivity	A star of the sixth magnitude
Accumulation time	0.528 second
Data on a star	120 points/page
Operating temperature	- 20 to 30°C
Electricity consumption	Electronic circuit portion: 7.5 W Electronic cooling portion: 3.2 W
Weight	3.7 kg
Dimensions	170 x 310 x 171 mm

The outdoor observation experiment for confirmation of the performance of the star sensor was conducted at Kakuta branch of the Aviation and Space Technology Institute. Through this observation, correspondence between the output of the star sensor and a constellation, the measurements of sensitivity, adjustment of the focus, correction of the angle of view, etc., were studied. A heat vacuum test and vibration test were conducted as environmental tests. Through these tests, it was confirmed that the functions of the star sensor were normal.

Data corresponding to one page of the star sensor is first stored in a memory, then it is transmitted to the ground at about the rate of one page every 2 minutes. This data is received at the tracking control centers located both in Katsuura and Kakuta of the National Space Development Agency. From this data, identification of the star observed through this sensor will be calculated by a large computer at the institute. It is possible to make an estimation of the position of the satellite.

Temperature Measurement

Tokyo KOGIKEN NYUSU in Japanese Jun 86 pp 6-7

[Article by M. Gomi, Airplane Pollution Research Group: "Simplification of CARS Temperature Measurements"]

[Text] The CARS (Coherent Antistokes Raman Spectroscopy) which has been studied as a noncontact type temperature measurement method for combustion measurements has practical problems such that the whole device, including a light source of YAG LASER, is complicated and expensive, and advanced software and a long processing time are needed in order to obtain temperature data. Therefore, when the spectral diffraction and analysis device used for the process to decide temperature by processing a spectrum of a signal light was improved, it was discovered that high-speed measurements, a drastic reduction in the cost of the signal processing system device, and simplification of measurements were possible when compared to the conventional measurement method.

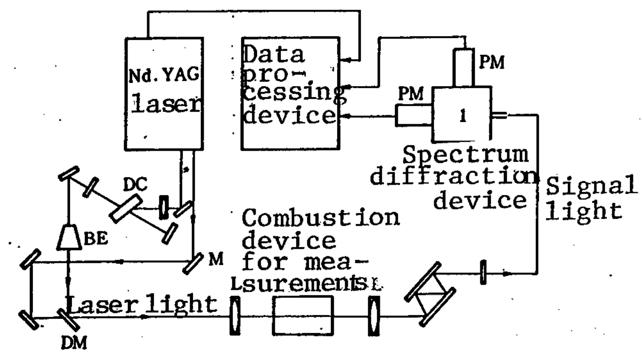

Figure 2. Outline of CARS Device

Regarding signal light processing, instead of the high-cost conventional device, which is composed of a combination of a high-performance spectral diffraction instrument and a multichannel light analyzer, the simplified spectral diffraction device and the new spectral diffraction analysis method were adopted. This was done by combining a small-sized spectral diffraction instrument and two units of photoelectron multiple tubes. In the past, in order to obtain temperature at one point, the collection of light spectrum information data for several hundred channels and their processing were necessary. Due to this new device and method, information data from only two channels is needed to be processed. Simple processing software and a handy computer can deal with the processing (refer to Figure 2). This device is presently applied to the study of lower pollution and higher load combustion instruments as part of the R&D on "general purpose sterling engines" conducted by the Agency of Industrial Science and Technology, Ministry of International Trade and Industry.

20,149/9365
CSO: 4306/2580

ENERGY

REPORT ON MEETING OF PETROLEUM COUNCIL'S OIL COMMITTEE APR 86

Tokyo SEKIYU SHIRYO GEPPO in Japanese Apr 86 pp 40-44

[Text] Agenda

1. Opening

2. Drawing up of an FY 1986-1990 oil supply plan.

3. Setting of an FY 1987-1990 oil stockpile target.

4. Regarding permission for the installation of oil cracking and distilling plants.

5. Establishment of an "oil development subcommittee" as a joint subcommittee of the Petroleum Council's Petroleum and Development Committees.

6. Setting up of a "subcommittee on gasoline distribution issues" as a joint subcommittee of the Petroleum Council's Petroleum and Gasoline Distribution Industry Committees.

7. Others

Reference Materials for Distribution

Data 1. Regarding recent international oil situations.

Data 2. Regarding deliberation on FY 1986-1990 oil supply plan.

Data 3. Reference materials for FY 1986-1990 oil supply plan (draft).

Data 4. Regarding viewpoints of export of oil products.

Data 5. Regarding deliberation on FY 1987-1990 oil stockpile target.

Data 6. Regarding deliberation for permission for installing oil cracking and distilling plants.

Data 7. Regarding establishment of joint subcommittees of Oil and Development Committees and of Oil and Gasoline Distribution Industry Committees of the Petroleum Council.

Data 8. Regarding the status of importing gasoline, etc.

Data 9. Regarding establishment of an oil industry revitalization center (foundation).

Data 10. Recent trends in oil product prices.

Data 2.

To: Chairman Jiro Enjoji of the Petroleum Council

Date: 16 April 1986

From: Michio Watanabe, minister of international trade and industry

Subject: FY 1986-1990 Oil Supply Plan

This is to refer to your council for deliberation, in accordance with provision 2 of Article 20 of the Petroleum Industry Law, the FY 1986-1990 Oil Supply Plan formulated as attached under the provisions of item 1, Article 3 of the same law.

Outline of FY 1986-1990 Oil Supply Plan (draft)
16 April 1986
MITI

1. Demand

A. The domestic demand for overall fuel oil in FY 1986 is predicted to decrease to 178.48 million kiloliters, 98.7 percent of demand a year ago, reflecting the increased demand in FY 1985 due to the severe winter and an increase in the domestic demand for bunker fuel oil used mainly by the electric power industry.

The domestic demand for overall fuel oil from FY 1987 onward is predicted to level off with some fluctuations until 1989, but in FY 1990 it is predicted to decrease to 176.39 million kiloliters, 98.1 percent of demand a year ago or 97.5 percent of the FY 1985 figure. The main factor for this trend is that while the domestic demand for gasoline and intermediate fraction will remain firm, the demand for bunker fuel oil used by the electric power industry and others is predicted to decrease, affected by the introduction of nuclear power generation and other substitute energies.

B. The main fuel oil for domestic demand by category is as follows:

a. With respect to gasoline, the domestic demand in FY 1986 is estimated at 36.987 million kiloliters, 100.6 percent of demand a year ago due to steady growth in the number of passenger cars and light cars owned, and from FY 1987 onward it is predicted to show a steady 0.6 percent increase annually following the same trend.

b. With respect to naphtha, the domestic demand in FY 1986 is predicted to decline to 24.176 million kiloliters, 98.7 percent of demand a year ago, because of the decrease in the domestic production of ethylene due to the increase in imports of ethylene derivatives from Saudi Arabia. In FY 1987 and 1988, it is predicted to show the same tendency, but in FY 1989 and 1990, the local production of ethylene is predicted to turn upward because the increases in imports from Saudi Arabia are expected to hit a peak with the domestic demand for naphtha also predicted to increase. As a result, the domestic demand for naphtha in FY 1990 is estimated to be 98 percent of the FY 1985 figure.

c. With respect to kerosene, the domestic demand in FY 1986 is estimated at 24.201 million kiloliters, 96.3 percent of demand a year ago, because the domestic demand for private sector use is expected to decrease reflecting the considerable increase in demand due to the severe winter in FY 1985, and demand for industrial use is also expected to continue to decrease. The total domestic demand from FY 1987 onward is predicted to level off, because while the domestic demand for private sector use is predicted to continue to increase 1 percent annually due to the growth in the number of households, demand for industrial use, which has been on the decrease as a heat source, is predicted to continue to decrease 2.3-2.5 percent annually.

d. With respect to diesel oil, domestic demand in FY 1986 is estimated at 26.616 million kiloliters, 103.1 percent of demand a year ago due to the increase in cargo transport traffic and in the number of trucks owned. The domestic demand from FY 1987 onward is predicted to have the same trend and to continue a steady 2.6 percent increase (from FY 1985 to FY 1990) on an annual average.

e. With respect to bunker fuel oil, the domestic demand in FY 1986 is estimated at 41.767 million kiloliters, 96.6 percent of demand a year ago despite the influence from the more or less decreasing crude oil price.

i. The domestic demand for electric power industry use is estimated at 20.01 million kiloliters, 98.5 percent of demand a year ago reflecting the increase in demand in FY 1985 due to the severe winter, the high operation of nuclear power generation plants, the start of coal thermal power plant operation, etc.

ii. The domestic demand for other uses is also predicted to decrease to 21.757 million kiloliters, 95 percent of demand a year ago.

With respect to the overall domestic demand for bunker fuel oil from FY 1987 onward, it is predicted to decrease slightly in FY 1988 and 1989, but in FY 1990 to sharply plunge to 88.3 percent of demand a year ago or 83.7 percent of FY 1985 figure for the following reasons:

i. The domestic demand for the electric power industry use from FY 1987 to 1989 is predicted to increase or level off due to a firm power demand, such as the start of a small-scaled operation of power plants.

ii. In FY 1990, however, it is estimated that domestic demand for electrical power use will sharply decrease to 78.5 percent of demand a year ago, or 81.9 percent of the FY 1985 figure due to the start of operations of large-scale nuclear power plants and coal thermal power plants, and the full-scale introduction of LNG from Australia.

C. With respect to petroleum gas, domestic demand is estimated at 16.214 million tons in FY 1986, 101.9 percent of demand a year ago, because the domestic demand for household business use, industrial use, etc., is predicted to remain firm and to continue increasing thereafter by 2.6 percent (from FY 1985 to 1990) on an annual average to reach in FY 1990, 113.7 percent of the FY 1985 figure.

2. Supply

A. With respect to imports, the import of gasoline, kerosene, and diesel oil in FY 1986 is estimated at 2.05 million kiloliters, 1 million kiloliter, and 400,000 kiloliters, respectively, from the oil companies' import forecasts. The import forecast for FY 1987 onward is conveniently formulated as growth rates equaling that of domestic demand. With respect to kerosene, on current condition that stable and occasional importing is possible, the stock level at the end of the first half of each year is set at 6 million kiloliters for some periods after FY 1986, a reduction of 700,000 kiloliters from the 6.7 million kiloliters of FY 1985 in accordance with the proposal made in the interim report of the Petroleum Committee's Subcommittee of the Petroleum Council dated 12 September 1985.

With respect to naphtha, import in FY 1986 is estimated at 1.362 million kiloliters, which would be adjusted according to the trends of domestic demand from FY 1987 onward, and in FY 1990 it is predicted to reach 102.2 percent of the previous year or 91.5 percent of the FY 1985 figure.

With respect to heavy oil, imports in FY 1986 are estimated at 7 million kiloliters, a reduction of 560,000 kiloliters from the estimated actual figure of FY 1985 and those for FY 1987 onward are predicted to level off.

Further, with respect to petroleum gas, import in FY 1986 is estimated at 12.343 million tons and from FY 1987 onward it is expected to increase reflecting a steady trend of domestic demand and to reach in 1990, 119.5 percent of the FY 1985 figure.

As a result, the import ratio to the domestic demand for oil products, including petroleum gas, is estimated to increase in FY 1986 to 19.1 percent, up 0.3 percent over FY 1985 and gradually to increase thereafter to reach 20.4 percent in FY 1990.

B. Production was estimated based on the above forecasts of domestic demand and imports.

In the first place, the production of overall fuel oil is estimated at 156.76 million kiloliters in FY 1986, 96.9 percent of the previous year, which would

however, be adjusted henceforth according to domestic demand, and to reach in FY 1990, 97.7 percent of demand a year ago, or 96.6 percent of the FY 1985 figure.

Moreover, the production of petroleum gas is estimated at 4.062 tons in FY 1986, 92.4 percent of production a year ago, fluctuating thereafter depending on the quantity of crude oil processing, etc., and is predicted to reach in FY 1990, 97.8 percent of the previous year or 93.3 percent of the FY 1985 figure.

As a result, the quantity of crude oil processing is estimated at 171.867 million kiloliters in FY 1986, 95.7 percent of processing a year ago, fluctuating thereafter depending on domestic demand and reaching in FY 1990, 97.7 percent of a year before, or 96.7 percent of the FY 1985 figure.

Crude oil import is estimated at 191.875 million kiloliters in FY 1986, 97.5 percent of a year ago, fluctuating therafter depending on the amount of crude oil processed and reaching in FY 1990, 97 percent of the previous year, or 94.3 percent of the FY 1985 figure.

C. Other important matters concerning oil supply.

In order to ensure the foundation for a stable oil supply over a long period, it is necessary for the oil industry to positively promote management improvement, including the voluntary closure of oil plants.

In order to properly carry out production according to demand trends for oil products forecast in this oil supply plan and to attempt the improvement of management of the oil refining industry, it is necessary to reduce in 3 years from 1986 the present processing capacity of topping plants by 110,000-160,000 kiloliters/day (700,000 to 1 million barrels/day).

FY 1986-1990 Oil Supply Plan (draft)

Data Material 3

(1) Production and Import Quantities of Crude Oil and Oil Products

Item			Unit	86 First half	86 Second half	86 FY	87	88	89	90
Crude oil	Domestic production		1,000 kl	360	420	780	890	950	1,140	1,500
	Import	For refining	"	78,777	93,915	172,692	179,710	178,040	176,540	171,900
		" nonrefining	"	8,960	10,223	19,183	14,920	14,830	14,920	13,770
		Total	"	87,737	104,138	191,875	194,630	192,870	191,460	185,670
	Grand total		"	88,097	104,558	192,655	195,520	193,820	192,600	187,170
Oil products	Production	Gasoline	"	17,534	17,433	34,967	35,180	35,410	35,640	35,860
		Naphtha	"	4,722	5,359	10,081	10,220	10,190	10,380	10,570
		Jet fuel oil	"	2,221	2,107	4,328	4,500	4,640	4,780	4,910
		Kerosene	"	9,757	13,074	22,831	23,200	23,200	23,200	23,220
		Diesel oil	"	12,805	13,621	26,426	27,240	27,910	28,570	29,160
		Heavy oil	"	26,442	31,685	58,127	59,230	57,770	57,430	52,590
		Total	"	73,481	83,279	156,760	159,570	159,120	160,000	156,310
		Petroleum gas	1,000 tons	1,892	2,170	4,062	4,180	4,170	4,190	4,100
	General import	Gasoline	1,000 kl	1,050	1,000	2,050	2,050	2,060	2,070	2,090
		Naphtha	"	6,620	7,000	13,620	13,380	12,860	13,150	13,440
		Kerosene	"	100	900	1,000	1,000	1,000	1,000	1,000
		Diesel oil	"	200	200	400	410	420	430	440
		Heavy oil	"	3,500	3,500	7,000	7,000	7,000	7,000	7,000
		Total	"	11,470	12,600	24,070	23,840	23,340	23,650	23,970
		Petroleum gas	1,000 tons	5,787	6,556	12,343	12,760	13,080	13,320	14,090
	Bonded import	Jet fuel oil	1,000 kl	995	1,255	2,250	2,260	2,270	2,280	2,290
		Heavy oil	"	2,770	2,840	5,610	5,840	5,960	6,070	6,180
		Total	"	3,765	4,095	7,860	8,100	8,230	8,350	8,470

Note: The imports of gasoline, kerosene, and diesel oil from FY 1987 were quantified for convenience as growth rates equaling to that of domestic demand.

(2) Capacity of Special Equipment (weighted average design capacity per fiscal year)

Item	Unit / FY	1986	1987	1988	1989	1990
Oil topping plant	1,000 kiloliters/ day	602	620	619	622	608
Oil quality improving plant	"	77	77	77	77	78
Oil decomposition plant	"	83	88	92	96	100

Note: The capacity of oil quality improving and decomposition plants shown in this table indicates the necessary plants for supplying gasoline.

(Reference 1) Forecast of Domestic Demand for Oil Products (Fuel oils)

(1,000 kiloliters; percent)

	FY 85 record (estimate)	FY 86 plan	FY 90 plan	FY 86 growth rate compared with 85	1990/1985 average annual growth rate	Component ratio		
						1985	1986	1987
Gasoline	36,767	36,987	37,956	0.6	0.6	20.3	20.7	21.5
Naphtha	24,504	24,176	24,011	▲ 1.3	▲ 0.4	13.5	13.6	13.6
Jet fuel oil	3,040	3,073	3,337	1.1	1.9	1.7	1.7	1.9
Kerosene	25,118	24,201	24,216	▲ 3.7	▲ 0.7	13.9	13.6	13.7
Diesel oil	25,816	26,616	29,421	3.1	2.6	14.3	14.9	16.7
A heavy oil	20,286	19,667	19,568	▲ 3.1	▲ 0.7	11.2	11.0	11.1
B heavy oil	2,111	1,993	1,730	▲ 5.6	▲ 3.9	1.2	1.1	1.0
C heavy oil	43,216	41,767	36,151	▲ 3.4	▲ 3.5	23.9	23.4	20.5
For electric power industry use	20,310	20,010	16,630	▲ 1.5	▲ 3.9	11.2	11.2	9.4
Others	22,906	21,757	19,521	▲ 5.0	▲ 3.1	12.7	12.2	11.1
Total of fuel oils	180,858	178,480	176,390	▲ 1.3	▲ 0.5	100.0	100.0	100.0
Petroleum gas (1,000 tons)	15,908	16,214	18,081	1.9	2.6	—	—	—

(Reference 2) Forecasts of Crude Oil Import, etc.

(1 million kiloliters; percent)

	FY 85 record (estimate)	FY 86 plan	FY 87 plan	FY 88 plan	FY 89 plan	FY 90 plan	FY 86 growth rate compared with 85	FY 90/85 average annual growth rate
Crude oil import	197	192	195	193	191	186	▲ 2.5	▲ 1.2
(Reference) Oil import in crude oil equivalent	246	243	246	244	243	239	▲ 1.5	▲ 0.6
Same as above (10,000 bbl/day)	424	418	423	421	420	412	—	—
Domestic demand for oil products (fuel oil)	181	178	180	179	180	176	▲ 1.3	▲ 0.5
(Reference) Domestic oil in crude oil equivalency	233	232	231	230	232	228	▲ 0.6	▲ 0.5

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ENERGY

ENERGY GENERATED IN FIRST HALF OF FY 1985

Tokyo DENKI TO GASU in Japanese Jun 86 pp 11-16

[Article by Research Office, Planning Division, Agency of Natural Resources and Energy, MITI]

[Text] The total generated electric energy in the first half of FY 1985 was 341.9 billion kwh, showing a steady growth of 5 percent over the same period in the previous year, 1984. This growth was due to the extension of equipment over the previous year by 1.4 percent in hydroelectric power generation, 2.6 percent in thermal power generation, and 20.6 percent in nuclear power generation, as well as to increased flow rate and smooth operations. For different energy source categories, hydraulic power generated 55.6 billion kwh, a high growth of 14.7 percent over the previous year. Meanwhile, the energy generated by thermal power was 211.3 billion kwh, which is 1.4 percent less than the previous year. However, this drop is due to our control of general demand and supply. Finally, nuclear power generated 75.1 billion kwh, showing a very high growth of 19.4 percent over the previous year.

I. General Electric Power Industry

(1) Nine major electric power firms and Okinawa Electric Power Co., Inc.

The nine major electric power firms generated a total of 250.1 billion kwh, a steady growth of 5 percent over the previous year. For different energy sources, hydraulic power generated 37.6 billion kwh, a high growth of 12.4 percent over the previous year, thanks to the increased flow rate at 100.7 percent (which was 92.5 percent in the previous year). Thermal power generated 143.7 billion kwh, which was 3.5 percent less than the previous year, and nuclear power generated 68.8 billion kwh showing a very high growth of 22.9 percent over the previous year.

The total energy generated by the Okinawa Electric Power Co., Inc. in the first half of FY 1985 was 2.3 billion kwh, which showed a steady growth of 2.5 percent over the previous year.

II. Other Electric Power Firms, Private Power Generators-Consumers

(1) Electric Power Development Co.

The Electric Power Development Co. generated a total of 17.8 billion kwh, a steady growth of 2.5 percent over the previous year. For different energy sources, hydraulic power generated 6.6 billion kwh, 14.4 percent more than the previous year, also thanks to the increased 99.8-percent flow rate (which was 80.7 percent in the previous year). The other source, thermal power, generated slightly less power than the previous year, 11.1 billion kwh, a drop of 1.4 percent from the previous year.

(2) Public electric power firms

The total electric energy generated by public electric power firms was 5.1 billion kwh, a steady growth of 8.4 percent over the previous year.

(3) Other electric power firms

Other electric power firms produced total energy of 29.2 billion kwh, a drop of 5.1 percent compared to the previous year. For different energy sources, hydroelectric power generated 920 million kwh, only 0.2 percent more, almost the same as in the previous year. Thermalpower generated 22.4 billion kwh, a drop of 4 percent from the previous year. Nuclear power generated 5.9 billion kwh, a big drop of 9.7 percent from the level in the previous year.

The total generated energy of the whole electric power business added up to 304.4 billion kwh, a steady and satisfactory growth of 3.9 percent over the previous year. For different energy sources, hydraulic power generated 50.2 billion kwh showing a high growth of 12 percent over the previous year, while thermal power generated 179.5 billion kwh, a drop of 3.3 percent from the previous year. Nuclear power generated 74.7 billion kwh, a very high growth of 19.5 percent over the previous year thanks to the extension of equipment and smooth operations.

(4) Private power generators-consumers

There were also private institutions which generated total energy of 37.5 billion kwh for their own consumption. It was a high growth of 15.4 percent over the previous year. For different energy sources, hydraulic power generated 5.3 billion kwh with an extraordinarily high growth of 48.7 percent over the previous year. Similar to other firms, this growth is the result of the increased flow rate compared to the previous year.

The energy generated using thermal power was 31.8 billion kwh, a relatively high 11.3-percent growth over the previous year. The growth of nuclear power was also high, 10.4 percent over the previous year, with 400 million kwh of generated energy.

Reference 1. Comparison of Flow Rates Between Nine Major Electric Power Firms and Electric Power Development Co.

(1) Nine electric power firms

(Unit: percent)

Year \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	(109.6) 101.9	(109.1) 89.0	(105.9) 112.4	(124.3) 115.7	(114.2) 106.4	(104.4) 90.3	(139.6) 108.6	(105.7) 125.0	(93.4) 108.4	(141.7) 125.7	(97.0) 94.9	(82.5) 93.4
1984	(81.8) 83.4	(76.9) 68.4	(54.8) 61.6	(81.2) 93.9	(92.5) 98.4	(113.5) 102.5	(89.0) 96.6	(69.9) 87.4	(66.4) 72.0	(47.7) 60.0	(67.2) 63.8	(73.7) 68.8
1985	(78.5) 65.5	(123.1) 84.2	(192.0) 118.3	(119.2) 111.9	(101.9) 100.3	(93.4) 95.7	(122.4) 118.2	(98.4) 86.0	(122.2) 88.0	(182.7) 109.6	(161.9) 102.9	(139.2) 95.8

(2) Electric Power Development Co.

Year \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	(—) 113.9	(—) 91.0	(—) 112.0	(154.7) 131.5	(165.1) 131.9	(121.9) 88.5	(149.2) 108.6	(86.7) 119.9	(69.4) 87.3	(143.2) 142.9	(80.8) 85.6	(56.7) 76.1
1984	(61.3) 69.8	(69.0) 62.8	(49.6) 55.5	(59.8) 78.6	(50.3) 66.4	(96.5) 85.4	(82.2) 89.3	(81.4) 97.6	(75.9) 66.3	(36.9) 52.7	(71.3) 61.0	(81.7) 62.2
1985	(77.5) 54.1	(138.2) 86.8	(233.2) 129.4	(158.0) 124.2	(152.7) 101.4	(113.1) 96.6	(131.6) 117.5	(79.1) 77.2	(118.1) 78.3	(186.0) 98.0	(146.4) 89.3	(147.1) 91.5

Note: Figures in ( ) in Tables (1) and (2) show the percentages taking those of the previous year as 100 percent.

Source: Annual Report

The total electric energy generated in calendar year 1985 was 670.4 billion kwh, showing a steady growth of 3.8 percent over the same period of the previous year, 1984. Compared to the approved capacity at the end of the previous year, the growth of each energy source was 1.2 percent in hydraulic power, 3.5 percent in thermal power, and a very high 24.5 percent in nuclear power. The growth of different energy sources was 91.1 billion kwh in hydraulic power, a growth of 23.9 percent; 427.3 billion kwh in thermal power, a drop of 4.1 percent; and 152 billion kwh in nuclear power, a very high growth of 19.9 percent over the previous year.

I. General Electric Power Industry

(1) Nine major electric power firms and Okinawa Electric Power Co., Inc.

The nine major electric power firms generated a total of 495.6 billion kwh in calendar year 1985, a steady growth of 3.8 percent over the previous year. For different energy sources, hydraulic power generated 61.9 billion kwh, a very high growth of 22.4 percent over the previous year. Thermal power generated 292.4 billion kwh, which was 6.7 percent less than the previous year, and nuclear power generated 141.4 billion kwh, showing a very high growth of 24.8 percent over the previous year thanks to the extension of equipment and smooth operations.

For the first and second halves of calendar year 1985, the total energy generated in the first half was 236.2 billion kwh, a steady growth of 3 percent over the same period of the preceding year. For different energy sources, hydraulic power generated 31 billion kwh, a high growth of 12.6 percent over the preceding year. Thermal power generated 136.9 billion kwh, which was 9.3 percent less than the previous year, and nuclear power generated 68.3 billion kwh, showing a very high growth of 34.6 percent over the previous year. The growth of nuclear power was due to the extension of Takahama Plants Nos 3 and 4 of the Kansai Electric Power Co., Inc., and Fukushima Plant No 3 of the Tokyo Electric Power Co., Inc., as well as to the smooth operations.

On the other hand, in the second half of calendar year 1985, the total energy generated was 259.4 billion kwh, still a steady growth of 4.6 percent over the previous year. For different energy sources, thermal [as published] power generated 30.9 billion kwh, a very high growth of 34 percent over the previous year. This increase of hydraulic power is due to the increase in approved output to 183,786 kw, to smooth operations, and to the increase of the flow rate. Thermal power generated 155.5 billion kwh, which was 4.3 percent less than the previous year, and nuclear power generated 73.1 billion kwh showing a high growth of 16.9 percent over the previous year, although it is not as remarkable as in the first half. The growth of nuclear power was due mainly to the extension of Sendai Plant No 2 of the Kyushu Electric Power Co., Inc.

(2) Okinawa Electric Power Co., Inc.

At the Okinawa Electric Power Co., Inc., the total energy generated in calendar year 1985 was 4 billion kwh, which showed a steady growth of 3.2 percent over the previous year. For the first and second halves of the year, the energy

generated in the first half was 1.8 billion kwh, a steady growth of 4.4 percent over the previous year, and in the second half it was 2.2 billion kwh, continuing the steady growth of the first half by 2.3-percent over the preceding year.

II. Other Electric Power Firms, Private Power Generators-Consumers

(1) Electric Power Development Co.

The Electric Power Development Co. generated a total of 33.5 billion kwh, a steady growth of 6.5 percent over the previous year. For different energy sources, hydraulic power generated 10.9 billion kwh, a very high growth of 20.2 percent over the previous year, while thermal power generated 226.3 billion kwh, a negligible growth of 0.9 percent over the preceding year.

For the first half of the year, the energy generated was 16.2 billion kwh, a growth of 2.9 percent over the previous year. For different energy sources, hydraulic power generated 5.3 billion kwh in the first half, a high growth of 13.6 percent over the previous year, while thermal power generated 10.9 billion kwh, a slight drop of 1.8 percent.

(2) Public Electric power firms

The total electric energy generated by public electric power firms was 8.4 billion kwh, an extraordinary growth of 25.5 percent over the previous year. For the first and second halves of the year, the energy generated in the first half was 4.4 billion kwh, a very high growth of 20.5 percent over the preceding year. In addition, the energy generated in the second half was 4 billion kwh and also showed a very high growth of 31.3 percent over the previous year. Similar to other hydropower plants, this growth is the result of the increased flow rate in 1985.

(3) Other electric power firms

Other electric power firms produced total energy of 56.8 billion kwh, a drop by 7.8 percent compared to the previous year. For different energy sources, hydraulic power generated 1.6 billion kwh, a high growth of 11.5 percent over the previous year, while thermal power generated 45.3 billion kwh, a drop by 4.6 percent from the previous year. Nuclear power generated 9.9 billion kwh, a big drop by 22.1 percent from the level of the previous year. This drop was due to periodic inspections executed during this year.

For the first and second halves of calendar year 1985, the total energy generated in the first half was 26.5 billion kwh, a drop of 10.5 percent from the previous year. For different energy sources, hydraulic power generated 800 million kwh, a very high growth of 19.4 percent over the previous year. Thermal power generated 22.5 billion kwh, which was only 0.7 percent more than the previous year, and nuclear power generated 3.2 billion kwh, showing almost an abnormal drop of 51.4 percent from the previous year. The drop in nuclear power was due to the periodic inspections of Tokai Plants Nos 1 and 2 and the Tsuruga Plant, and the overall drop is also a result of the drop of nuclear power generation.

In the second half of calendar year 1985, the total energy generated was 30.3 billion kwh, also a drop of 5.2 percent from the previous year. For different energy sources, hydraulic power generated 800 million kwh, a growth of 11.7 percent over the previous year, although it is not as remarkable as in the first half. Thermal power generated 22.9 billion kwh, which was 9.3 percent less than the previous year, and nuclear power generated 6.7 billion kwh, a growth of 9.8 percent over the previous year because the periodic inspections had ended and the operation of equipment was smooth.

The total energy generated of the general and other electric power businesses in calendar year 1985 added up to 598.3 billion kwh, showing a steady growth of 3 percent over the previous year. For different energy sources, hydraulic power generated 82.7 billion kwh with a very high growth of 22.3 percent due to the higher flow rate than the previous year. Meanwhile, thermal power generated 364.4 billion kwh, a drop of 5.9 percent from the previous year. Nuclear power generated 151.2 billion kwh, a very high growth of 20.1 percent over the previous year thanks to the extension of large-capacity equipment and smooth operations.

For the first and second halves of the year, the total energy generated in the first half was 285 billion kwh, an almost negligible growth of 1.8 percent over the previous year. For different energy sources, hydraulic power generated 41.5 billion kwh, a relatively high growth of 13.7 percent over the previous year. Thermal power generated 172.1 billion kwh which was a drop of 7.5 percent from the previous year, and nuclear power generated 71.5 billion kwh showing a very high growth of 24.7 percent over the previous year.

On the other hand, in the second half of 1985, the total energy generated was 313.2 billion kwh, a growth of 4.1 percent, which is slightly higher than the first half. For different energy sources, hydraulic power generated 41.2 billion kwh, a very high growth of 32.3 percent over the previous year, while thermal power generated 192.3 billion kwh, which was 4.4 percent less than the previous year. Nuclear power generated 79.7 billion kwh, a high growth of 16.3 percent over the previous year.

(4) Private power generators-consumers

Private institutions generated total energy of 72.1 billion kwh for their own consumption. It was a relatively high growth of 10.6 percent over the previous year. For the first and second halves of 1985, the total energy generated in the first half was 33.5 billion kwh, a steady growth of 6.6 percent over the previous year. For different energy sources, hydraulic power generated 3.3 billion kwh, a relatively high growth of 10.7 percent over the previous year. Thermal power generated 29.5 billion kwh, a steady 4.3-percent growth over the previous year. Although nuclear power generated 700 million kwh, we will not mention its comparison with respect to the previous year for both the first and second halves because executions of periodic inspections have made comparison inadequate.

Reference 2. Equipment Utilization Factors

(1) Nine electric power firms

(Unit: 1,000 kw, percent)

Energy source \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hydraulic power	22.6 19.0 14.7	20.3 16.6 18.8	29.6 17.3 31.5	42.0 33.7 40.9	41.5 37.0 38.3	32.9 37.1 34.4	39.7 35.7 44.6	38.7 28.1 28.8	32.7 21.6 27.2	30.9 15.1 27.9	21.8 14.6 22.5	22.3 16.4 21.2
Thermal power	44.8 46.7 47.1	50.6 52.8 49.3	44.6 53.2 39.8	33.0 40.0 33.3	31.1 33.6 31.6	39.5 39.8 37.6	41.6 49.8 44.9	46.6 54.8 52.3	42.8 43.8 46.2	35.6 43.3 37.0	44.0 44.7 40.7	47.1 46.6 42.3
Nuclear power	59.5 69.9 86.0	56.3 65.7 82.4	57.2 57.2 85.5	64.1 59.8 76.1	68.9 69.8 86.1	70.9 67.5 74.0	73.0 69.7 74.0	81.5 74.1 78.2	84.6 78.7 70.6	88.0 79.0 75.9	78.6 81.8 72.9	79.4 87.0 82.8
Average	42.3 44.2 46.8	45.3 47.4 48.5	43.3 46.9 45.3	39.0 42.2 41.4	38.3 39.4 41.3	42.4 43.3 43.1	45.4 50.0 49.7	49.7 52.4 52.1	46.4 44.7 46.9	41.7 43.0 42.0	44.2 44.3 43.1	46.3 46.7 45.6

(2) Electric Power Development Co.

Energy source \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hydraulic power	17.2 14.1 12.9	14.6 12.8 13.8	17.2 11.6 18.3	24.4 15.8 23.6	27.6 19.0 23.1	18.8 26.1 21.6	26.0 24.4 34.0	28.1 22.9 20.6	19.9 13.0 15.8	21.8 10.5 16.3	13.0 9.4 13.2	15.4 11.2 16.3
Thermal power	82.4 84.5 81.3	85.4 87.6 81.9	66.8 65.2 79.3	69.9 52.0 69.0	70.3 69.9 56.4	64.5 76.8 64.0	78.0 83.1 83.6	81.8 79.5 34.7	66.9 80.4 77.9	63.5 58.1 67.8	73.4 61.5 61.4	76.5 78.6 84.8
Average	36.8 38.7 36.9	38.4 39.0 37.6	34.6 30.4 39.7	40.3 28.6 36.5	42.5 36.9 34.7	34.8 43.8 36.4	44.2 45.0 51.4	46.9 42.7 43.0	36.3 36.6 37.5	36.4 27.2 34.1	34.1 27.6 29.8	36.8 34.8 39.9

Note: In each column in Tables (1) and (2), upper figures are for 1983, middle figures are for 1984, and lower figures are for 1985.

On the other hand, the total energy generated in the second half was 38.6 billion kwh, a growth of 14.4 percent over the previous year, which is higher than in the first half. For different energy sources, hydraulic power generated 5.1 billion kwh, an abnormally high growth of 76.1 percent over the previous year. This growth was due to the comparison between 1984, which was a dry year, and 1985, in which the flow rate was very high. Thermal power generated 33.4 billion kwh, also a high growth of 10.9 percent over the previous year.

[Boxed item] (Note) The figures are obtained by rounding off. Therefore, the sum of these rounded figures will not always add up to the totals given above.

Table. Generated Energy in First Half of FY 1985

Month / Enterprises	Apr	May	Jun	Jul	Aug	Sep	First half total
9 major firms							
Hydraulic power	7,019	6,818	5,933	7,986	5,145	4,708	37,609
Thermal "	19,120	18,729	21,553	26,620	31,005	26,660	143,687
Nuclear "	10,372	12,138	11,132	11,506	12,166	11,443	68,757
Subtotal	36,511	37,685	38,619	46,111	48,316	42,811	250,053
Okinawa Electric Power Co.	270	349	371	443	428	414	2,275
Electric Power Devel Co.							
Hydraulic power	1,102	1,113	1,009	1,647	996	738	6,604
Thermal "	1,737	1,467	1,610	2,172	2,202	1,960	11,147
Subtotal	2,838	2,580	2,619	3,819	3,198	2,698	17,751
Public (hydraulic power)	1,161	923	818	1,072	638	488	5,099
Others							
Hydraulic power	199	183	162	179	130	65	919
Thermal "	3,436	3,439	3,574	3,875	4,267	3,795	22,389
Nuclear "	886	882	1,000	1,049	973	1,149	5,938
Subtotal	4,520	4,504	4,736	5,103	5,370	5,012	29,246
Wholesale total	8,520	8,007	8,178	9,994	9,206	8,197	52,097
General electric power industry							
Hydraulic power	9,481	9,037	7,923	10,884	6,908	5,999	50,232
Thermal power	24,563	23,983	27,108	33,110	37,903	32,831	179,498
Nuclear "	11,258	13,020	12,132	12,554	13,138	12,592	74,695
Subtotal	45,301	46,040	47,163	56,548	57,950	51,422	304,425
Private generators-consumers							
Hydraulic power	702	692	634	1,225	1,052	1,027	5,335
Thermal power	4,633	4,771	4,567	6,017	5,794	6,014	31,796
Nuclear "	119	123	119	10	0	0	370
Subtotal	5,454	5,585	5,320	7,252	6,848	7,042	37,500
Total							
Hydraulic power	10,183	9,729	8,557	12,109	7,962	7,026	55,566
Thermal power	29,195	28,754	31,675	39,126	43,697	38,846	211,294
Nuclear "	11,377	13,143	12,251	12,564	13,138	12,592	85,065
Total	50,755	51,626	52,483	63,799	64,798	58,464	341,925

Table. Generated Energy in Calendar Year 1985 (Unit: 10^6 kwh)

Enterprises \ Month	Jan	Feb	Mar	Apr	May	Jun	First half total	Jul	Aug	Sep	Oct	Nov	Dec	Second half total	Total
9 major firms															
Hydraulic	2,601	3,011	5,586	7,019	6,818	5,933	30,967	7,986	5,145	4,708	5,002	3,913	4,130	30,883	61,851
Thermal	27,675	26,179	23,663	19,120	18,729	21,553	136,919	26,620	31,005	26,660	22,054	23,681	25,431	155,451	292,370
Nuclear	12,119	10,426	12,041	10,372	12,138	11,132	68,288	11,506	12,166	11,443	12,427	12,011	13,529	73,083	141,370
Subtotal	42,395	39,676	41,299	36,511	37,685	38,619	236,175	46,111	46,111	42,811	39,483	39,605	43,090	259,416	495,592
Okinawa Electric Power Co., Inc.	272	255	282	270	349	371	1,799	443	428	414	372	275	291	2,233	4,032
Electric Power Development Co.															
Hydraulic	624	602	885	1,102	1,113	1,009	5,336	1,647	996	738	790	619	787	5,577	10,913
Thermal	2,113	1,922	2,061	1,737	1,467	1,610	10,909	2,172	2,202	1,960	1,723	1,511	2,157	11,724	22,633
Subtotal	2,737	2,524	2,946	2,838	2,580	2,619	16,244	3,819	3,198	2,698	2,513	2,130	2,913	17,302	33,516
Public (hydraulic power)	277	383	801	1,161	923	817	4,363	1,072	638	488	572	533	691	3,993	8,356
Others															
Hydraulic	51	62	138	199	183	162	794	179	130	65	152	139	90	756	1,550
Thermal	4,227	3,749	4,034	3,436	3,439	3,574	22,459	3,875	4,267	3,798	3,606	3,468	3,867	22,881	45,341
Nuclear	103	89	255	886	882	1,000	3,215	1,049	973	1,149	1,185	1,135	1,176	6,666	9,881
Subtotal	4,381	3,899	4,426	4,520	4,504	4,736	26,468	5,103	5,370	5,012	4,943	4,742	5,131	30,303	56,772
Wholesale total	7,396	6,806	8,173	8,520	8,007	8,173	47,076	9,994	9,206	8,197	8,028	7,405	8,768	51,598	98,674
General electric power industry															
Hydraulic	3,553	4,057	7,416	9,481	9,037	7,923	41,461	10,884	6,908	5,999	6,516	5,204	5,698	41,209	82,670
Thermal	34,287	32,105	30,040	24,563	23,983	27,108	172,086	33,110	37,903	32,831	27,755	28,944	31,746	192,290	364,376
Nuclear	12,222	10,575	12,296	11,258	13,020	12,132	71,503	11,554	13,138	12,592	13,612	13,147	14,705	79,748	151,251
Subtotal	50,062	46,738	49,745	45,301	46,040	47,163	285,049	56,548	57,950	51,422	47,883	47,295	52,149	313,217	598,297
Private generators-consumers															
Hydraulic	203	342	583	702	692	634	3,256	1,225	1,054	1,027	781	555	488	5,131	8,387
Thermal	5,552	4,886	5,109	4,633	4,771	4,567	29,518	6,017	5,794	6,014	5,083	5,118	5,397	33,421	62,911
Nuclear	121	111	123	119	123	119	715	10	0	0	0	0	27	36	751
Subtotal	5,976	5,339	5,815	5,454	5,585	5,320	33,488	7,251	6,848	7,042	5,864	5,674	5,912	38,591	72,079
Total															
Hydraulic	3,856	4,399	7,992	10,183	9,728	8,557	44,717	12,109	7,962	7,026	7,297	5,760	6,186	46,341	91,057
Thermal	39,839	36,991	35,149	29,195	27,754	31,675	201,604	39,126	43,697	38,846	32,839	31,063	37,143	225,713	427,317
Nuclear	12,342	10,686	12,419	11,377	13,143	12,251	72,218	12,564	13,138	12,592	13,612	13,147	14,731	79,781	152,002
Total	56,037	52,077	55,560	50,755	51,626	52,483	318,538	63,799	64,798	58,464	53,748	52,969	58,061	351,838	670,376

Note: The figures are obtained by rounding off. Therefore, the sum of these rounded off figures will not always add up to the totals given above.

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NEW MATERIALS

HIGH-PERFORMANCE THERMOSETTING RESIN REPORTED

Tokyo NIKKO MATERIALS in Japanese May 86 pp 32-36

[Article by Teruho Adachi: "Future Materials"]

[Text] 1. Preface

Voyager-II has shown views of Uranus at the outskirts of the solar system via a 3 billion mile probing journey of 8½ years. The Space Shuttle Challenger disaster occurred only 4 days after a round of applause was given to the achievement of Voyager-II. The accident, fresh in our memories, brought grief to the world. Mankind's hopes for space, broadcasting satellites, space factories, and planetary probes are endless in spite of this tragedy. A group of macromolecules called "Thermosetting Resin" and optoelectronics are used as indispensable elements in rockets and space equipment. Optoelectronics is in the vanguard of the information revolution.

2. What is a high-performance thermosetting resin?

The synthetic macromolecule is broadly classified into thermoplastic resin and thermosetting resin. A thermoplastic substance can be melted with heat. Polyethylene, nylon, etc., can be cited as typical thermoplastic resins. They are giant molecules in which more than several thousand atoms are combined linearly. Film, spinning, etc., are formed by heating, melting, extracting, and casting such molecules. Polyethylene bag, resin bucket, synthetic fiber, etc., are familiar products made of thermoplastic resin.

In contrast, the thermosetting resin itself is not a macromolecule, but is mere low-molecular weight compound with a number of reactive groups in molecules. Although it does not possess any characteristics as a resin, when it is formed, it will be highly polymerized and hardened by causing a reaction to heat and by netting the structure. The history of thermosetting resin originated in the Bakelite (phenol resin) which is a synthetic macromolecule developed for the first time in the world in 1907. Subsequently, urea resin and melamine resin were developed. These resins including the Bakelite have widely been used for tableware, polywood, paint, etc. In recent years, many resins such as unsaturated polyester resin, silicone resin, polyurethane resin, epoxy resin, etc., have been commercialized. The amount of plastics produced in Japan in 1985 is 9.1 million tons. The amount of thermosetting resin produced in the country in the same year accounts for about 20 percent (1.64 million tons) of the 9.1 million tons.

Characteristics required in macromolecular materials have been diversified, specialized, and advanced in proportion to the fact that in recent years, macromolecular materials have been used in various fields, particularly in high-technology fields as important materials. In these new fields, there are many cases in which resins are used as composite materials made with other substances or are used as materials in which fine functional elements are encapsulated, rather than being used singularly. It is necessary to apply high pressure to thermoplastic resin for the purpose of extruding melted macromolecules with high viscosity and to enhance the temperature of the thermoplastic resin for the purpose of heating and melting the thermoplastic resin when it is formed, because it is highly polymerized in advance. There are many cases in which the application of high-pressure and the rise in temperature will be obstacles to thermoplastic resin when it is used as a composite material made with other substances or is used as a material in which fine functional elements are encapsulated. On the other hand, the thermosetting resin is a liquid or solid low molecule with low softening point; it will become an insoluble and infusible macromolecule only due to reaction when it is formed. Therefore, fine functional elements can be encapsulated in such thermosetting resin, and the thermosetting resin can be used as a composite material along with other substances in moderate conditions of pressure and temperature. In addition, the thermosetting resin has few problems such as loss of fine functional elements, etc. Also, it is easy to change the chemical structure of molecules and to give multiform functions to thermosetting resin. When the hardened thermosetting resin is three-dimensional, it will be insoluble and infusible and will be excellent in resistance to heat, chemicals, etc. Such thermosetting resin has highly been evaluated, because these features meet today's needs. Research on new thermosetting resins is being conducted so they can possess high function and high performance and can be used in high-technology fields.

3. IC Package

Today's information revolution is based on the development of technology of semiconductors, particularly the IC. Rapid increase in integration degree from IC to LSI and to VLSI and rapid reduction in cost of the IC's have supported the spread of miniaturization of information processing systems. The thermosetting resin important in this IC field is an epoxy resin used as an IC package.

Semiconductor elements are packed in some form to protect them from humidity, impact, etc. As shown in Figure 2, a hermetic seal and a resin seal are methods of sealing semiconductor elements. The hermetic seal means that semiconductor elements are put in gas, shut off from the outside with ceramics or the like, and the resin seal buries semiconductor elements in resin. In most cases, the latter method is used, because it is excellent for mass production and good price.

In the case of fine semiconductor elements, when they are sealed, intensive pressure cannot be applied to them, and they will be subject to thermal restriction. Therefore, thermosetting resin, special high function epoxy resin is used as an optimum material for sealing these semiconductor elements. This epoxy resin is of cresol (novolac) type, and is excellent particularly in

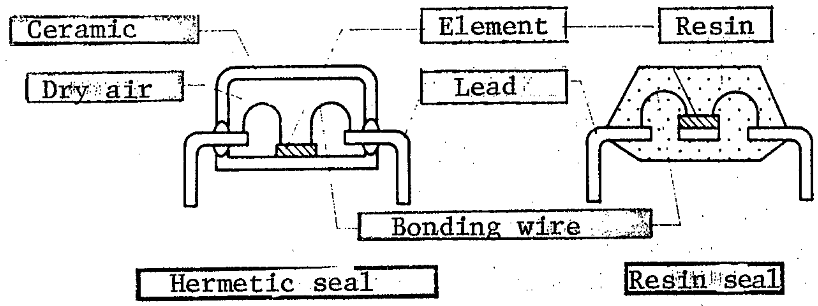

Figure 2. Method of Sealing Semiconductors

humidity resistance, heat resistance, and adhesion. The reliability of IC's is affected greatly by the quality of resin, because resin must adhere directly to semiconductor elements with a view to sealing them. More severe conditions have been required for resin as a sealing material in proportion to rise in IC's integration degree. The decrease in reliability of IC's over a long period of time is caused by the following--when water soaking into sealing materials (IC packages) reaches the aluminum electrode of semiconductor elements, and when ionic impurities exist therein, aluminum corrosion will occur therein. For this reason, a high-purity epoxy resin has been developed by reducing the amount of such ionic impurities to less than several parts per million. This resin is used frequently. However, not only these ionic impurities, but also other impurities (hydrolytic chlorine) have become problems in proportion to the rise in IC's integration degree (64K, 256K, etc.). The other impurities are combined organically. They may be generated by a side reaction caused during synthesis, may be decomposed under existence of water, and may generate chloric ions. Therefore, it is absolutely necessary to reduce the amount of such other impurities as well as ionic impurities for the purpose of enhancing the IC's integration degree. IC packages were made by using resins with the different content of hydrolytic chlorine, and were subjected to an accelerated test at a high temperature of 121°C, a high pressure of 2 kg per square cm and a high humidity of 100 percent. Figure 3 shows results of the accelerated test.[1] Definitely, the results are correlated to electrical characteristics. It is possible to cope with the coming 1M DRAM age, the amount of these impurities has been reduced presently up to about 100 parts per million at most.

In the future, the damage of semiconductor elements will become a problem in proportion to the promotion of rise in IC's integration degree (4 megabits, 16 megabits, etc.), use of larger chips, and use of thinner wires. This damage is caused by stress generated by a difference between silicon elements and thermal expansion coefficient. Therefore, an epoxy resin with low stress and high heat resistance or a completely new thermosetting resin is being studied.

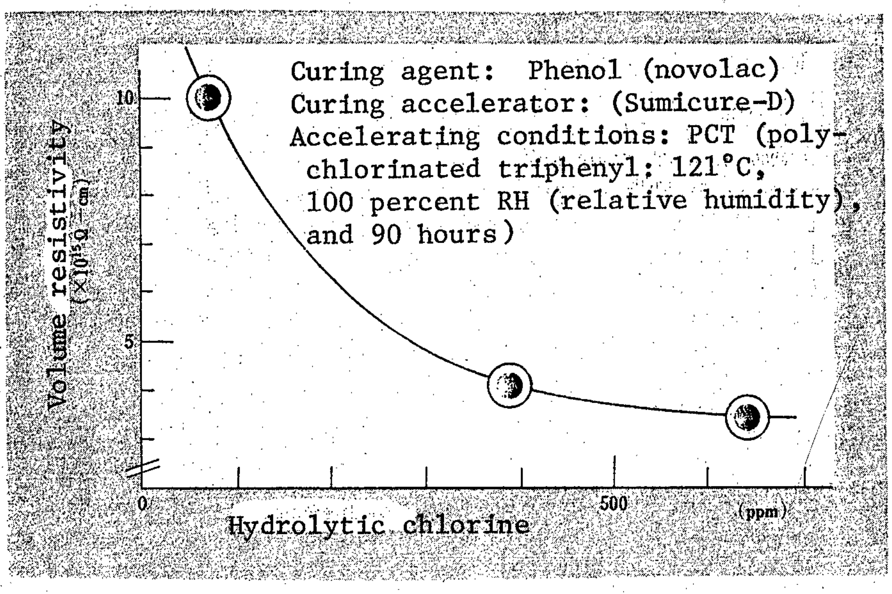

Figure 3. Hydrolytic Chlorine Contained in Epoxy Resin and Electrical Characteristics of Sealing Materials

4. High-Density Multilayer Printed Circuit Laminate

When electronic equipment such as desktop calculator, televisions, etc., are disassembled, it can be seen that electronic parts are mounted on a board on which circuits are made with copper foil. This board possesses the element mounting, connecting, and insulating functions. It is made by etching a copper circuit, after thermosetting resin is impregnated and laminated with a reinforcement such as paper, glass textile, or the like, and is hardened by laminating copper foil. A paper phenol resin board has been used for private demands such as televisions, and a glass textile epoxy resin board has been used for industrial and communication demands such as computer, etc.

Also, in this field, the rise (use of narrower circuits) in wiring density and wiring diversification have been promoted rapidly in accordance with increase in IC's mounting density and use of higher IC's integration degree. Usually, two wires (circuit width: 150 to 180 micrometers) are put in a pin interval (2.54 mm) of IC's. But, three or four wires (circuit width: less than 100 micrometers) are put in such pin interval of new IC's. These new IC's are being put to practical use. Also, complex circuits can be made by adopting a multilayer structure made by putting an insulation layer in intervals of circuits and by piling up these circuits. Circuits which consist of more than 30 layers are used in supercomputers. The disconnection of circuits or layers will occur unless the dimensional stability of heat is high in these circuits and layers. This heat is generated when these circuits and layers are processed or used. Therefore, a resin with high heat resistance is required. A resin with very high heat resistance and imide structure has been developed, because conventional epoxy resins cannot be used for such circuits and layers. Table 1 shows an example of a resin based on imide. This resin

Table 1. Heat Resistant Resin and Physical Properties of Laminate

Physical properties of laminate \ Resin base	Present product (epoxy)	Heat resistant resin (imide) (epoxy)*
Heat resistance: Tg (°C)	107	216
Thermal expansion coefficient: 20 to 260°C (percent)	>10	2.54
Copper foil peel strength (kg per m)	187	232
Solder resistant heat at a temperature of 300°C (minute)	2	>5

*T-SM made on an experimental basis by Sumitomo Chemical Co., Ltd.

is excellent in heat resistance and dimensional stability as compared with today's epoxy resins. Therefore, high density and high multilayer can be obtained.

5. ACM

A lightweight, strong, and high-performance composite material is called "ACM (advanced composite material)." The ACM is reinforced with carbon fiber, aramid fiber, boron fiber, etc. A typical ACM is CFRP (carbon fiber reinforced plastic). The CFRP has widely been used in sports equipment such as tennis rackets, fishing rods, in Japan. It has also attracted attention in the West, particularly the United States, and has been developed as a material for space equipment and aircraft. Worldwide use of carbon fibers in 1984 was 2,800 tons. Thirty-seven percent of the 2,800 tons were used as a material for space equipment and aircraft. Sixty-two percent of the carbon fibers used in the United States is used in space equipment and aircraft. Importance is attached to performance rather than cost of military aircraft and space equipment. There is a strong possibility of particularly ACM being used in such military aircraft and space equipment. For example, about 3 tons of CFRP is used in the Harrier, V/STOL (vertical short take-off and landing) fighter. About 3 tons of CFRP is equivalent to 26 percent of the structural weight including the weight of main wings of the fighter. CFRP is also used in nose cone, storehouse doors, fuselage of booster rockets, of the space shuttle. One and a half tons of ACM mainly, CFRP is used in the rudder, etc., of civil aircraft such as the Boeing 767, the newest jet passenger airplane. As mentioned up to now, the ACM contributes to reduction in weight and rise in fuel efficiency.[2]

Epoxy resin has been used as a thermosetting resin called, "Matrix Resin" combined with fiber reinforced materials, because it is a well-balanced resin with respect to moldability, cost, and mechanical and physical properties. However, a rise in resin characteristics, particularly heat resistance and toughness has been required in proportion to the increase in range of applications of resins in the space and aircraft industries. Figure 5 shows the

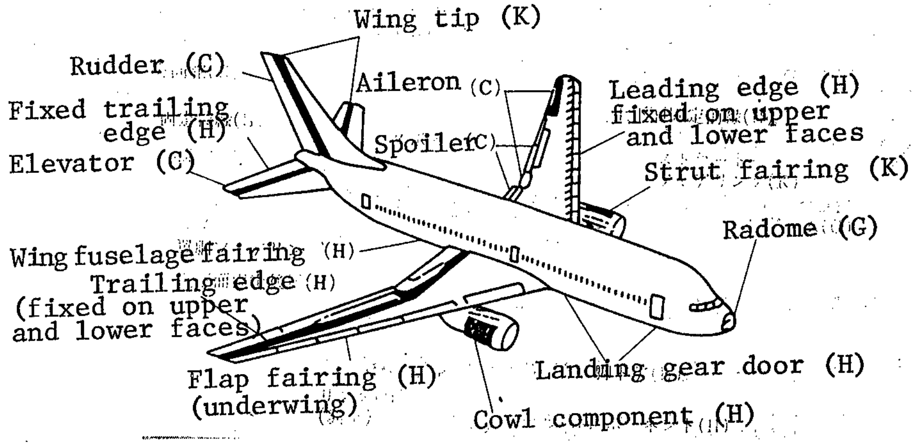

Figure 4. Structural Materials[2] of Boeing 767

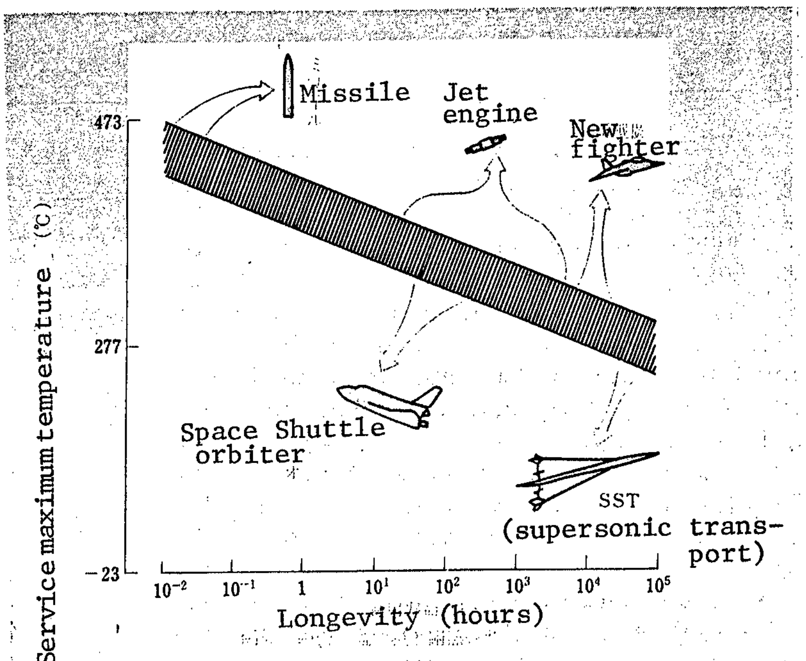

Figure 5. Relation Between Heat Resistance[3] and Space Equipment and Aircraft

example of required heat resistance.[3] A new matrix resin which replaces the epoxy resin is required to satisfy the required heat resistance.

There are two tendencies for new resins. One is a modification or improvement of epoxy resin, and the other is a polyimide type thermosetting resin. Table 2 shows the improvement of epoxy resin. New resins are being developed so that they can have the heat resistance and mechanical strength much higher than those of resins used in sports equipment. But, of the new resins, those based

Table 2. Kind of Epoxy Resins and Physical Properties of CFRP

Resin base	Epoxy resin		Sports grade	Present aircraft grade	New heat resistant resin
			ELA-128*	ELM-434*	ELM-100**
	Curing agent		4.4'-diaminodiphenyl sulfone		
Physical proper-ties	Heat resistance: TG (°C)		220	241	261
	Interlaminar shear strength (kg/mm)	Room temperature	8.8	12.7	13.1
		121°C	--	8.7	9.2

*Put on the market by Sumitomo Chemical Co., Ltd.
**Developed on an experimental basis by Sumitomo Chemical Co., Ltd.

on epoxy have the limit in the rise of heat resistance, and the most sensational topic at present is the development of resins based on thermosetting imide. The U.S. National Aeronautics and Space Administration is developing the polyimide of norbornane end and acethylene end, and is studying the resin based on (bismaleimide), which is excellent in moldability. Comparing the ALCN resin[4] which is a resin based on (bismaleimide) and the present heat resistant epoxy resin for aircraft with each other, as shown in Figure 6, the ALCN resin is excellent in moldability, and the heat resistance of the ALCN resin is about 100°C higher than that of the epoxy resin.

In the future, ACM's employing new resins will be adopted as materials for space, military aircraft, and civil aircraft, and the main structural material for aircraft will probably be changed from metal to ACM in the 1990's. In addition, it is anticipated that light weight and tough aircraft be flying worldwide. Also, these aircraft will be excellent in reliability and fuel efficiency.

6. Ultraviolet Radiation Curing Resin and Information Field

Now, new thermosetting resins are attracting worldwide attention. These resins are three-dimensional and cured by irradiating UV (ultraviolet rays) to it. Some of the resins are being developed enthusiastically in the optoelectronic field, because they possess the characteristic whereby they can be cured rapidly (at a second or less) by irradiating UV to them and can be patterned by using a mask. The other resins which have been put to practical use are used to cut copper foil circuit patterns of the previously mentioned laminate. In addition, a large amount of such resins are used as surface protective agents. Also, as shown in Figure 7,[5] the coating material of optical fibers is being changed from conventional thermosetting resin to UV curing resin excellent in mass production at the developmental stage of these new thermosetting resins. Even UV curing resin employing imide groups is being studied so that it can be used practically in passivation films and alpha ray protective coat of LSI's which require heat resistance.

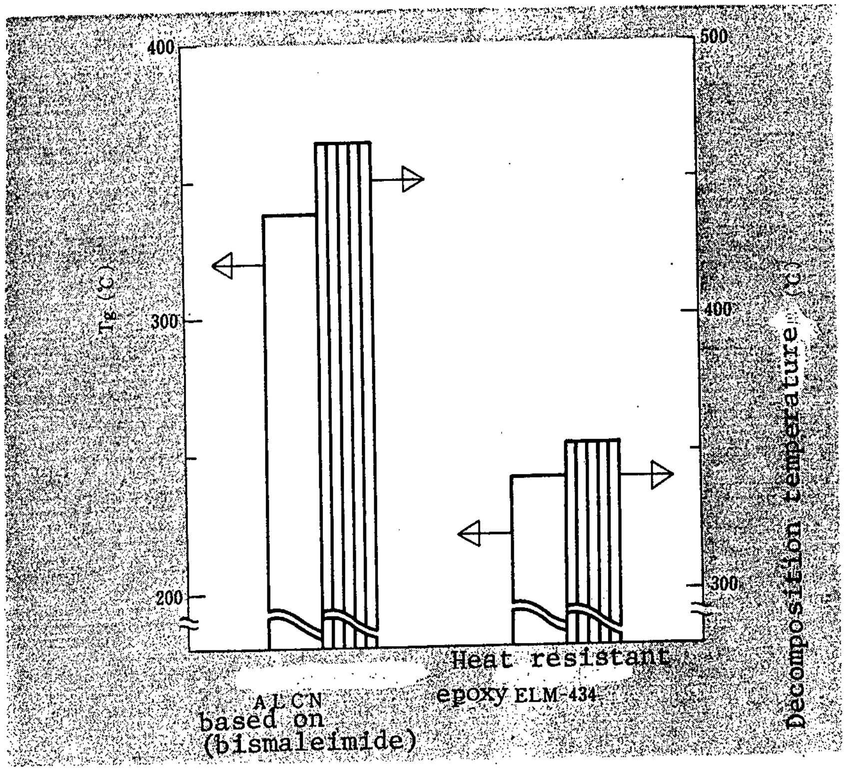

Figure 6. (Bismaleimide) Resin and Heat Resistance

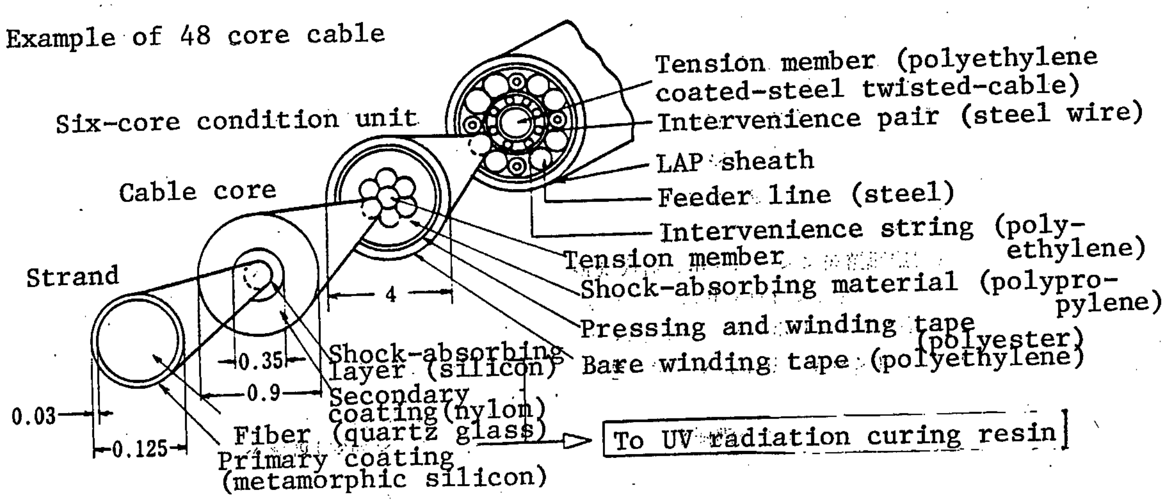

Figure 7. Example of Optical Fiber Cable Structure (Unit: mm)[5]

In addition, it is possible to actually pattern and prepare circuit elements of optical IC's in the future by using a UV curing resin which can be used to control the refractive index.

7. Conclusion

This article has described the trend of R&D of high-function thermosetting resin. High-function thermosetting resin is also being studied in other fields. Footnote 6 refers to the outline of macromolecules.

It is expected that the thermosetting resin will provide endless possibilities for material chemists in the future, because this resin can be selected as a curing component from many compounds, functions can be readily given to the resin, and the resin can be developed as a composite material in reply to increasing diversification and high-function of such resin.

FOOTNOTES

1. Adachi, MACROMOLECULAR PROCESSING, Vol 34, 1985, p 373.

2. Yorita, MACROMOLECULE, Vol 33, 1984, p 625.

3. Kobayashi, PLASTICS, Vol 34 No 7, 1983, p 38.

4. Kanegawa, Adachi, POLYMER PREPRINTS, JAPAN, Vol 34 No 10, 1985, p 3077.

5. Katayama, NIKKO MATERIALS, Vol 3 No 11, 1985, p 32.

6. MACROMOLECULE, Special Report, "Thermosetting Resin Suitable for New Generation," Vol 34 No 3, 1985.

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NEW MATERIALS

PROSPECTS FOR ULTRAPOLYMERIC POLYETHYLENE FIBER DISCUSSED

Tokyo NIKKO MATERIALS in Japanese Jun 86 pp 14-17

[Article by Hirotoshi Shibata: "Does New Fiber Surpass Kevlar?"]

[Excerpt] Kevlar (brand name) is a para-aramid fiber developed by Du Pont (De Nemours & Co.) in the United States. Recently, an ultrahigh-molecular-weight-polyethylene (UHMW-PE) fiber has come into the limelight as a fiber whose strength and elasticity surpass those of Kevlar. Until now, Kevlar has been highly evaluated as the strongest fiber, particularly among commercialized fibers. But because the new fiber is stronger than Kevlar, it has taken over the top position. This new fiber is said to have excellent resistance to wear, chemicals, weather, etc., and possesses the quality of "lightness." What is the UHMW-PE fiber? How do manufacturers cope with this new fiber? What are the future prospects for the new fiber? I will describe these problems in detail.

"Character" of Polyethylene Is Extended to Upper Limit

It has been said that it is possible to develop a polyethylene fiber that would surpass carbon fibers, aramid fibers, etc., in strength and elasticity modulus. According to theoretically calculated limit values, it is possible to attain a strength of 240 grams per denier (the thickness of a fiber when a material with a weight of 1 gram is extended to 9 kilometers). This value is about nine times greater than the 28 grams per denier of Kevlar, which is presently the strongest para-aramid fiber. Also, its elasticity modulus is 2,950 grams per denier. This value is about 1.2 times that of the 2,500 grams per denier of the highest elastic carbon fiber. But like other synthetic fibers, the polyethylene fiber has so far attained only a small fraction of the theoretical limit values. This is due to the fact that while these are limit values obtained when various elements are theoretically extended to their utmost limits, fibers have so far been produced only through technical processes where the mixing conditions of regularly arranged crystal portions and irregularly arranged amorphous portions can be only partly oriented. This means that the molecular chains forming the crystal structures of various elements are oriented, and crystals are as large and complete as possible in a taut condition.

By contrast, the UHMW-PE fiber is obtained by orienting the molecular chains to an ideal condition and bringing them close to their limit values. This fiber was industrialized 7 years ago by a research group of Dutch State Mines Co., Ltd. (DSM) in the Netherlands. The research group discovered a new spinning process called the "gel spinning method" in which polyethylene is first dissolved in a solvent so it is in a gel condition when it is spun. As a result, it has been possible to realize the ideal structure. Also, the use of giant macromolecular polyethylene with a molecular weight on the order of 1 million, the so-called UHMW-PE, has resulted in a linear arrangement of long, tough polymer that further increases its strength. The UHMW-PE fiber possesses the same characteristics as those of conventional polyethylene. That is, it possesses the same slip and electrical characteristics. It also has excellent resistance to chemicals, weather, and water. In addition, it possesses the following features: 1) Its wear resistance is four times that of cast nylon and 16 times that of polyacetal. 2) Its wear resistance at cryogenic temperatures is several times that of polycarbonate. These characteristics and features are also possessed by the UHMW-PE fiber.

MPI Aims at Becoming a Consistent Manufacturer

The only companies presently manufacturing the UHMW-PE fiber are Toyobo Co., Ltd. and Mitsui Petrochemical Industries, Ltd. (MPI) in Japan, and Allied Corp. in the United States. MPI has independently developed a UHMW-PE fiber. Toyobo and Allied have obtained a license from DSM. Although these companies, with the exception of Allied, have small-scale pilot plants, it is anticipated that they will launch into commercialized production of the UHMW-PE fiber.

The brand name of the UHMW-PE fiber made by Allied is "Spectra 900." Both the strength and elasticity modulus of the Spectra 900 fiber are 1.5 times those of Kevlar. It is said that its wear resistance and flexural fatigue strength are about six times those of Kevlar. Last year Spectra 900 created a great sensation in the United States. At present, in the United States, which has special national circumstances, it is used mainly in the woven cloth of bulletproof vests.

DMS and Toyobo will soon construct intermediate plants, but they have not advanced to the commercialization of the UHMW-PE fiber. The brand name of the UHMW-PE fiber made by Toyobo is "Dyneema." On the other hand, MPI has said: "We will decide to mass-produce the UHMW-PE fiber by the end of fiscal 1986 at latest." The company is actively seeking to commercialize the UHMW-PE fiber, following after Allied Corp., and is attracting worldwide attention.

Of the above manufacturers, MPI is the only company that consistently manufactures UHMW-PE fibers by using an UHMW-PE resin. For reference, the companies which manufacture UHMW-PE resin are Hoechst AG in West Germany, Hercules Chemical Co., Ltd. in the United States, MPI, Asahi Chemical Industry Co., Ltd., and Nippon Petrochemicals Co., Ltd. The average molecular weight of this UHMW-PE resin is on the order of 2.5 to 5 million, which is 100 times that of general-purpose high-density polyethylene. For

this reason, the UHMW-PE resin has the disadvantages of high melting viscosity and bad fluidity. Although the price per kilogram is about Y600, the amount of UHMW-PE resin used in the United States, Europe, and Japan is small, being about 10,000 tons, 10,000 tons, and 1,500 tons, respectively. This is also due to poor workability. Manufacturers have made efforts to develop new working technologies for the UHMW-PE resin.

MPI has started to develop a new fiber in order to extend the use of the UHMW-PE resin. MPI does not use the gel spinning method. Theirs is called the "melt orientation stretching method," to which in-house technologies used in polyethylene and polypropylene are applied. In this method molecules are ideally arranged in parallel by orienting the molten UHMW-PE resin and by stretching out the folded crystal structure into a long molecule. MPI says that "the use of the gel spinning method would require much labor to put the polyethylene in and take it out of the solvent, but the melt orientation stretching method will not require as much effort. Therefore, the use of the melt orientation stretching method is less expensive than the gel spinning method."

Uses in Sports and Marine Equipment

The features of a special fiber, "Tekmilon" (brand name) made by MPI, are as follows: Its strength (35 grams per denier) is 1.25 times that of Kevlar (28 grams per denier). Its elasticity modulus (1,000 grams per denier) is the same as that of Kevlar. Tekmilon has excellent weather resistance. That is, it experiences only a small reduction in elasticity modulus after being exposed to the sun. It also has excellent creep characteristics. That is, it undergoes only a very slight elongation on the order of 0.4 percent over 1,000 hours when a load of 1 gram per denier is applied to it at a temperature of 35°C. Therefore, Tekmilon is superior to Kevlar in these respects.

Tekmilon is available in three shapes: monofilament, multifilament, and tape. MPI believes that Tekmilon can be used alone for ropes--such as marine rope and fishing lines--woven and unwoven fabrics--such as bulletproof vests and safety belts--and in nets--such as fishing nets and safety nets. MPI also believes that it can be used as a composite material for sports and leisure equipment, acoustic materials, automobile parts, and medical supplies.

Nippon Gakki Co., Ltd. has already adopted Tekmilon as a reinforcing material in a new model of skis this year. In addition, Tekmilon has tentatively been used for bowstrings, tennis racket frames, sailcloth, etc. MPI will further extend the use of Tekmilon in the future. In particular, the company intends to extend the use of this fiber primarily in fields that require strength and lightness, because the fiber has a specific gravity only 0.96 that of water. For example, the fiber will be used in developing ropes for submarine resources. If the aramid fiber (Kevlar) and carbon fibers are used to develop resources in the deep ocean, they will not be able to withstand their dead loads, because their specific gravities are large, being 1.45 and 1.80, respectively. On the other hand, it has been

disclosed that the UHMW-PE fiber can be used at an ocean depth of about 12,000 meters, because this fiber is light and will not break at great depths. It seems that this fiber will be used mainly for marine purposes.

From the standpoint of fuel expenses, the automobile and aircraft industries have made efforts to lighten the bodies of automobiles, aircraft, and spaceships since the oil shock of the 1970's. MPI feels that Kevlar will be used in the automobile and aircraft industries as a lightweight reinforced fiber to replace carbon fibers, and there is a possibility of the market for Kevlar being extended.

Material Attracting Worldwide Attention as an ACM

MPI is planning to sell the UHMW-PE fiber independently as a composite product in accordance with its use, and is also planning to sell it in the form of fiber and prepreg, because the company regards it as a prop for the advanced composite material (ACM) business. Of course, however, the company will primarily sell structural materials such as woven fabrics, tension members of ropes and optical fibers, etc., possessing the characteristics of lightness and strength.

As mentioned, MPI is buckling down to the business of the UHMW-PE. In the same way, other companies such as Toyobo Co., DSM, etc., are enthusiastically promoting it.

But while UHMW-PE is a really attractive fiber, it has one major drawback: Its usable temperature is low, being only 80-100°C. From the start, polyethylene has not had excellent heat resistance. For this reason, at present, the usable temperature of the UHMW-PE fiber is also low. This drawback must be taken up in future research. But all of these companies have already begun research toward enhancing the fiber's heat resistance, and this problem will probably be solved in the near future.

Even at the present time, the UHMW-PE fiber is excellent in wear resistance, strength, elasticity modulus, specific gravity (lightness), etc., and its price per kilogram is Y8,000 to 9,000. This price is almost equal to the list price (Y6,000 to 10,000) of Kevlar, but actually, the UHMW-PE fiber is less expensive than Kevlar, because of the difference between their specific gravities. It seems that if the heat resistance of the UHMW-PE fiber possessing these features is enhanced, UHMW-PE will completely replace Kevlar and the demand for UHMW-PE will be increased. Also, the UHMW-PE fiber must be improved in the future so it can possess physical properties closer to its limit value. The present UHMW-PE fiber clearly possesses physical properties that are equivalent to or surpass those of Kevlar. However, its strength and elasticity modulus are still only about one-seventh and one-third of the limit values, respectively. There is still a good possibility that the UHMW-PE fiber can be improved. It can be anticipated that research on extending various elements to the utmost limit will unexpectedly reveal new physical properties. Therefore, this research is worthy of note.

Synthetic Fibers Face a New Generation

The development of the UHMW-PE fiber has exerted a large influence on other fibers. A new spinning process called the "liquid crystal spinning method" for Kevlar was invented and developed with the aim of putting it to practical use. In the same way, new spinning processes called the "gel spinning method" and the "melt orientation stretching method" for this UHMW-PE fiber were invented and developed with the aim of putting it to practical use. In other words, familiar materials were changed into high-performance fibers. In particular, the "gel spinning method" invented by DSM has exerted a large influence on fiber technologies.

Under this impetus, the Kuraray Co. has developed a product called Vinylon RM by gel-spinning Vinylon, which is used mainly in industrial unwoven fabric and the meshes of nets. The Young's modulus of this Vinylon RM is increased by about 30 percent. Vinylon RM is used in the field of fiber reinforced cement to reinforce mortar concrete, because it possesses the following features: 1) It has excellent hydrophilic and fiber characteristics. 2) Its fibrous surfaces have concave and convex portions. 3) It has excellent adhesive properties with hardened substances such as cement, etc.

Allied Corp. in the United States has developed a fiber with high strength and elasticity modulus by gel-spinning an UHMW-PVA (ultrahigh-molecular-weight-polyvinyl alcohol) compound.

In addition, it seems that research organizations across the world intend to develop a new fiber with high strength and elasticity modulus by using condensation resins such as nylon, Tetron, etc.

As mentioned, some fibers have already been commercialized, and others will be commercialized in the future. These new developments have created a great sensation throughout the world. In the future, high-function fibers developed by gel-spinning various materials will be commercialized in the wake of Vinylon RM.

The high-function fibers developed successively in the 1980's include carbon fibers, aramid fibers, alumina fibers, boron fibers, ceramic fibers, silicon carbide fibers, and UHMW-PE fibers. These fibers have already been commercialized. From now on, various fibers will be developed successively by using Vinylon, Tetron, nylon, PVA, etc. In these circumstances, it is presently uncertain if the UHMW-PE fiber will really replace Kevlar and will be used in a number of fields, or if it has merely created a sensation and is destined to disappear. It is obvious, however, that the future of the fiber depends on how manufacturers will extend its use and buckle down to research on future fibers.

It can be said that the UHMW-PE fiber will completely replace Kevlar if the demand for this fiber is stabilized in the fields of fishing nets, ropes used for developing submarine resources, etc., and if use of the fiber can be further extended to marine purposes together with wide use in aircraft, spaceships, medical equipment related to biotechnology, etc. In addition,

if its heat resistance--which is its only problem--is enhanced, the use of the fiber will be extended increasingly and the position of the fiber will be naturally consolidated. It seems that some of the UHMW-PE resin manufacturers will further extend the use of the fiber in the future. But, the present UHMW-PE fiber manufacturers should further extend the use of this fiber itself, and will certainly do so.

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SCIENCE AND TECHNOLOGY POLICY

LONG-TERM VISION FOR INDUSTRIAL STRUCTURE DISCUSSED

Roundtable Discussion

Tokyo TSUSAN JANARU in Japanese Aug 86 pp 16-21

[Roundtable discussion with: Jiro Ushio, chairman of Ushio Electrical Manufacturing Company; Takemochi Ishii, professor of Tokyo University; Shunpei Kumong, professor of Tokyo University; and Shinji Fukukawa, permanent vice-minister of MITI (former chief of the Industrial Policy Bureau)]

[Text] On 26 May, The Planning Subcommittee of the Industial Structure Council's Comprehensive Division published a final report entitled "Basic Plan for an Industrial Society in the Twenty-First Century--Towards International Cooperation in Industrial Structure and Fusion of Creative Knowledge." Japan is rapidly approaching the year 2000, and this report searches for new directions in trading and industrial policies focusing on three aspects of the future industrial society: international, creative, and cultural. In short, the report clarifies [basic] concepts in medium- and long-term industrial structure policies for the future of Japan.

Why Was the Basic Plan Necessary?

Fukukawa: Since July of last year, the Industrial Structure Council has been working on a "Basic Plan for an Industrial Society in the Twenty-First Century." This was motivated by the fact that dramatic changes are taking place in our industrial society. Firstly, "prosperity of only one country" cannot occur any more, though Japan is accumulating a huge surplus in the current [trade] balance. So far, Japan has taken the international economic stability for granted, but now we must extricate ourselves from this "thinking like a small country." We have entered an era in which we must decide how to harmonize Japan's economy with and what role to play in the international society. Secondly, large-scale changes that alter the operating mode of an industrial society, such as technological innovations and progress toward information oriented society, are taking place. This may trigger a great turning point in the conventional, twentieth century engineering systems. Thirdly, various changes are occurring in our social structure and awareness, creating [new] lifestyles and living culture. These changes are exerting new

influences on the economy.

In considering Japan's future course and policies, we should not watch the world through a telescope from Japan, as we have done so far. Rather, we should behold our industrial policies from outside the earth, and discover harmony with the world. Since economy is very complicated, intended effects are not achieved unless [economic] policies are developed along multiple paths. Since the oil crisis, the zero-sum notion has become popular, but [we should ask ourselves] whether there are formulas to direct these changes toward a positive-sum notion. This report was prepared after discussions along these lines. I would like to hear first from you [Ushio] how to perceive the currents of the time.

Epochal Significance of the "Basic Plan"

Ushio: The main differences between these discussions [in the report] and past arguments about industrial structure are (1) that this report considered a long-term outlook with a 15-year cycle and (2) that internationalization was regard as a structural phenomenon and long-term responses were considered accordingly. As a result, Japan's full-set doctrine of "providing anything important domestically," which has been Japan's policy for the last 100 years since the Meiji reign began, or the past 40 years since the end of World War II, has been revised. The report unequivocally declares that horizontal diversification will be pursued in many fields. I totally concur. MITI has insisted on an industrial full-set doctrine so far. Therefore, it is epochal that MITI has declared to accept the importing of basic necessities and replacing 70 billion dollars of Japan's export with overseas products.

Moreover, another new idea in the report is that Japan must continue to maintain a high growth rate of at least 5.5 percent while these changes are being introduced. The report concludes, therefore, that technological innovations are important to achieve such goals. MITI has maintained that basic research is important; now, in addition, MITI is touting the virtues of technological fusing and hybridizing hardware and software as well as advanced technologies of different industries. MITI is envisioning overseas advances through international cooperation, while competitive capability is enhanced through such fusion and hybridization.

Based on these ideas, I consider this report to be MITI's international declaration acknowledging that Japan has become an advanced country both industrially and commercially and MITI is ready to fundamentally change its basic policies from now on.

Ishii: There has been some criticism about technology fusion and hybridization. For instance, the accepted theory underestimates Japan's combination technology, but many commercial products popular in Japan are from such technology. It is clear from the detailed analysis of statistical data by Professor Fumio Kodama of Saitama University for over ten years that technology fusion has become the prime mover of today's high technology, in response to MITI's policies. This is why we can now discuss [policies] based on [technology fusion].

What is emphasized in the report is a total-about face from [the standpoint] of surviving by exporting, but these new policies can be justified with confidence and meticulous thinking. First of all, [Japan has] technical confidence. In other words, Japan has almost succeeded in converting to advanced technologies and is now beginning to lead the pack. For instance, Japan is breaking even in technology trading and clearly will stay in the black in the future. Another achievement is that Japan has revolutionized its self-image by overcoming the oil crisis with its own technology, which was centered on conserving energy. We must use the same approach in the future, as we had great success so far. If we carefully analyze the current situation step by step, then we certainly reach the same conclusions as this report.

Kumong: After I read the report, I also was impressed by how well Japan has reached this stage and felt that we have come a long way. Our vision of our trade and industry policies in the eighties was based on the three pillars of "coexistence of allowance and vitality" for the domestic part, "overcoming the limitations of a country poor in resources" internationally, and a "knowledge-concentrated industry." This, however, is still a view held in Japan, not from the outside. Also, the Temporary Investigation Council emphasized only two points: domestically "establishing a welfare society with vitality," and "aggressively contributing to international society" overseas. When compared to these, the proposals in the present report are more advanced.

In international relations, the political influence of the third world became stronger during the seventies through the oil crisis and other events. These events forced us to focus our attention on topics, such as the new order in international economics and the north-south problem. Now, major western countries again have the responsibility to manage the world through cooperation and solidarity. Actually, these countries are showing their strength to do so. This report is pointed in that direction by not simply mentioning positive contributions but also by making deep commitments to formulate and maintain a new international economic order through cooperation and solidarity among major countries.

Domestically, the report also not only recommends pursuing both abundance and vitality but proposes to aggressively create new lifestyles. I consider this to be a positive step forward. Although I believe it is easier to say we will create new lifestyles than to do so, I think it is very significant that these goals are actually hoisted toward the twenty-first century.

Moreover, the report clearly proposes that the third industrial revolution will serve as the technical and economical foundation to support these two goals. This is a point still being disputed among scholars, but it is significant that the industrial society is divided into the first, second, and third, roughly spaced by 100 years each.

Harmony with the World

Ushio: This is the first report with such a clear definition of trends. The report states that "pain and suffering are to be expected," but it does not

say what to do with the pain and suffering in discussing future visions, which is why the report is very stimulating. It is too good a report to set aside after it is published. In the future, it is necessary for MITI to bring the report to the attention of everyone and thoroughly discuss it.

Ishii: Many countries around Japan are beginning to have technological confidence, and this report will stimulate them as well. In contrast to many long-term outlooks offered so far, this one is likely to accelerate the historical evolution of countries around us. Such changes will echo back to Japan and provide us with vitality. These countries are, in a sense, the most vigorous countries in the world, and I believe that their vitality will repeatedly resonate with each other and be amplified in the future.

Kumong: Some argue that "Japan sings sweet songs but cannot carry out anything." Surely, there is some truth to this. What Japan did in the past few years, however, were not little things grudgingly yielded under external pressure. These were the years we have toiled to clarify our future outlook as a great evolution is taking place in world history. The outlook in this report is a part of Japan's effort to aggressively speak out. It is desirable to have lively discussions about the report in order to move forward.

Fukukawa: As for the [trade] frictions, there are institutional and noninstitutional factors, but the latter will rapidly grow in the future. Since Japan has grown so much now, Japan will not be able to survive in the world unless these noninstitutional factors are cleverly harmonized. Hence, this basic plan aims to solicit lively discussions in every sector of our society about our future relationship with the international community and the direction for living culture.

Ushio: Until the oil crisis, Japan had been a skilled craftsman for production rationalization. Since then, Japan has been called "high-tech Japan" by the world. Hence, today's expensive yen will become totally different in a few years, such as "internationally cooperating Japan" or "Japan with a new lifestyle." The idea of coexistence and coprosperity throughout the world mentioned in this report--we cannot prosper alone unless everyone else is also affluent--is an idea Japan initiated.

Fukukawa: Now that Japan has gained a certain amount of technical competence and is capable of overseas investments, government's policies must also watch the world market to maintain international coexistence and cooperation.

Ishii: With the current strength of the yen, Japan's share of the world's economic activities is now over 10 percent, reaching almost 20 percent when we include NICS [newly industrialized countries] in our neighborhood. Therefore, it is natural that the government should pay attention to world business.

Kumong: I believe that the meanings of words such as cooperation and solidarity have changed. In the past, each [country] had its own turf and cooperation and solidarity meant to be friendly while keeping one's own turf. Now, solidarity should be interpreted differently because we must include the whole world and so should others. In other words, every country now has

become an administrative unit responsible for the whole world. This, I believe, will force [them] to cooperate and join together.

Ishii: Sometime ago, a report prepared by a policy study committee appointed by Prime Minister Ohira wrote that we had come to a holistic path. I sense that what was predicted a few years ago has become a reality in the form of a holistic market.

Ushio: Triggered by this event, not only trade policies but also our economic activities are changing in the same direction as the administration. This, in turn, forces all existing institutional systems to change. For instance, for a business to follow this trend, from 30 to 40 percent of its total assets will be in foreign holdings and from 10 to 20 percent of its employees will work overseas, even for a manufacturer. When economic activities become international to this extent, then such business activities cannot be protected only by Japan; it is clear that they must depend on daily protection by foreign governments. This will necessitate international standardization and generalization of, say, tax systems.

Ishii: Education will be another example.

Kumong: At present, an awareness revolution is under way. About 10 years ago, the phrase cosmic consciousness was popular. Now it is holistic consciousness. These phrases have something in common; they represent a great transformation and revolution in the meaning of one's attitude, comparable to the self-awareness that symbolizes the modern generation. This has already taken place widely in advanced countries and is rapidly spreading in Japan now.

Ishii: One of the reasons that the Japanese are strongly aware of this holistic concept is the progress in information dissemination. Data from the whole world are instantaneously passed to every corner of the country. Tokyo's role as one of the world's information centers is rapidly becoming more significant.

New Fusion

Ushio: I can testify as one of the participants of the committee's work that this report was composed only after thorough verifications of data collected from every source, government and private. We have not predetermined policy directions; rather, we clearly stated facts based on substance. A confident manager is said to freely show his plants to others claiming that "I can build a better plant if someone imitates ours." A similar idea runs in this report. In this sense, this is a report with allowance. (Laughing)

Ishii: That allowance is now extended to lifestyle and culture in the report. It may be historical that MITI began to emphasize lifestyle and culture instead of producing merchandise. So far, leisure has been considered to be diametrically opposite of working.

Ushio: While preparing the report, we often argued whether "MITI should

concern itself with such things, " but these things serve as the fertilizer for creative future developments. In this sense, they are exactly the agenda to be discussed by MITI. At present, only 2 to 3 percent of MITI's personnel are working on the consumption of time or money; this should be increased to 30 or 40 percent.

Kumong: Expenses for durable consumer goods occupy a large portion of our consumption. From the consumer's viewpoint, however, such expenses form assets that enhance the quality of life by providing various useful services for extended periods. Hence, it is wrong to count expenses for durable goods simply as consumption. I believe we should think more carefully about defining savings only in terms of monetary assets.

Fukukawa: On this point, the report proposes to "fuse creative knowledge" from different technologies. Certainly, Japan is now ready to take off on creative technology development. In a way, I feel that the second stage of a two-stage rocket has been ignited.

Ushio: Only Japanese believe that Japanese people are not creative, while the concept of high-tech Japan is well established throughout Japan.

Ishii: I think what will follow this crisis of the expensive yen will be a more serious pursuit of high technology and its establishment.

Ushio: We have, however, one urgent problem--our new lifestyle is primitive. On this issue, we are from 10 to 20 years behind. Hence, a sequel to this report should include more sections on leisure, beginning with encouragement to spend money "to appreciate beauty and create leisure," though the money may have been earned doing something else.

Fukukawa: That is true.

Ushio: Thus, this report should be humble enough to admit that it has done only one half of the work needed. However, even that half is epoch making and we should thoroughly discuss this report, without getting bored.

Fukukawa: New fusion of international aspects, technological creativity, and living culture will proceed, leading to a new era.

Ushio: Isn't the role of the administration in the future to act as a catalyst and provide energy for such a fusion? In this sense, the hidden role of MITI is great.

Fukukawa: Our time is up. I thank you very much for your interesting discussions.

Industrial Structure Council Report

Tokyo TSUSAN JANARU in Japanese Aug 86 pp 22-28

[Text] On 26 May, the Planning Subcommittee of the Industrial Structure Council's Comprehensive Division, which is a consulting organization of the Minister of International Trade and Industry, published a report entitled "Basic

Plan for an Industrial Society in the Twenty-First Century--Towards International Cooperation in Industrial Structure and Fusion of Creative Knowledge."

There are only 15 years left before we enter the twenty-first century. Discussions were held since the summer of 1985 to search for new directions in international trade and industrial policies. These discussions looked into the future industrial society from the following viewpoints: (1) the future of Japan's industrial structure in harmony with the international economic society and contributing to the international society (international aspects); (2) the future of Japan's industrial structure coping with changes in various domestic economic factors, such as technological innovations and dependence on data (creativity); and (3) the future of Japan's industrial structure which will be affected by new cultural life styles resulting from diverse value judgements and a longer life expectancy.

The subcommittee published an interim report, titled "Basic Plan for an Industrial Society in the Twenty-First Century (Interim Summary Centered on International Aspects)," on 6 February prior to the final report. This report was completed prior to the final report because it was felt that analyses and suggestions from international viewpoints should be expedited under circumstances that required urgent responses to various problems associated with unbalanced external relationships. The contents of the interim report are also incorporated as basic ideas into a report released on 7 April (the so-called Maekawa Report) by the Economic Structure Coordination Study Group for International Cooperation, which counsels Prime Minister Nakasone.

This final report added more examinations from the viewpoints of creativity and cultural aspects to the interim report, resulting in a more comprehensive content. At the same time, the Maekawa Report's theme was expanded in the final report with more concrete directions for future policies.

This report is fairly long, a total of 104 pages on A4-size paper. Its basic ideas are briefly summarized in the following.

In order to achieve three goals that challenge Japan's industrial society, which is marching toward the year 2000, Japan must take following actions. These three goals are: (a) harmony with the international economic society and contribution to the international society; (b) expansion of industries into new frontiers in response to changes in domestic economic factors, such as technological innovations and reliance on data; and (c) appropriate responses to the creation of a new living culture.

(1) With strengthened coalition among major countries, basic stabilization policies must reflect macroscopic economic policies guided by domestic demands and fundamentals of resulting exchange rates.

(2) Through expanded, direct overseas investments and accelerated importation, international division of labor must be accomplished in harmony with the international economic society, and Japan's share of international public assets must be increased.

(3) On the other hand, high domestic growth rates should be achieved by using the growth potential based on domestic demands. At the same time, by promoting the fusion of creative knowledge, Japan should expand new frontiers in industry and promote service and high-touch [labor intensive?] industries. Diminishing employment opportunities, which will result from promoting international division of labor, must be absorbed by aggressive policies to transform industrial structure.

Pushing these reforms will certainly result in pain and suffering on every industry and social class, though severity may vary. Choosing these actions, however, simply means to pursue long-term national benefits for the future of Japan. This is why we strongly expect that the actions proposed in this report will steadily be carried out with deep understanding and wide support from industry, labor, and all classes of people.

In the "Basic Plan for an Industrial Society in the Twenty-First Century," two directions for industrial structure, which faces the twenty-first century, to aim toward have been proposed. The first direction is "international cooperation" through increased importation, direct overseas investments, and promotion of technology transfer with the goal of establishing international division of labor in harmony with the international economic society. The other direction is the "fusion of creative knowledge" with the goal of "opening up new industries by creating new knowledge that did not exist before through organic coupling and fusion of diverse technologies and knowledge accumulated in various sectors of the society."

Of these goals, the basic idea of "international cooperation" in the industrial structure has already been proposed in the "Interim Report" released in February of this year, which we have already reported in this journal. On the other hand, this "fusion of creative knowledge" is a new concept included for the first time in this final report as the basic direction to open up new industries in order to absorb the negative effects of "international cooperation" on domestic industry. In this article, we will focus on this fusion of creative knowledge and provide a commentary that includes a somewhat quantitative analysis of various economic factors. These factors served as the background for ideas and the actual course of actions proposed in the final report.

1. Diverse Development of Knowledge Activities--Fusion of Technologies

At present, the role of knowledge activities by industry, such as research, development, and product planning, is very important; these activities serve as the driving force for economic development and advancement of industrial structure. In contrast to production elements such as capital and labor, quantitatively describing knowledge activities is not necessarily easy. For instance, according to preliminary calculations by the Economic Planning Agency, in which the stock of technical knowledge accumulated by capital investments in research and development was included as one of the production elements and its contribution to the economic growth rate was measured using the production function, the contribution exhibited a rising trend: about 65

percent from 1971 to 1975, about 70 percent from 1976 to 1980, and about 75 percent from 1981 to 1984. These results clearly show that, for the past decade, knowledge has led Japan's economic development.

Moreover, qualitative changes are taking place in today's industrial knowledge activities. For example, industrial research and development have diversified far beyond those of traditional industries and are being expanded to be more global and spread across different industries. Under these circumstances, new technologies are being created by combining technologies from different fields, that is, fusion of technologies is in progress. We will analyze this trend by quantitative methods.

Research expenditures classified according to industries and products are presented as a matrix (matrix of data about an industry's payments for research in products), which was included in the "Report of a Survey on Science and Technology Research" ([prepared by] General Affairs Agency). Let the research expenditures spent by different industries i and j on products be M_i and M_j, respectively, and define a technology fusion index r_{ij} between the two industries (see Fig. 1 (a)) as follows. Then, the technology fusion index between the ith and jth industries,

$$r_{ij} = \frac{M_i \cdot M_j}{[(M_i \cdot M_i^T)(M_j \cdot M_j^T)]^{1/2}} = \frac{(M_i, M_j)}{|M_i| \cdot |M_j|}.$$

(The superscript T stands for a transposed matrix.)

In other words, the technology fusion index is a scalar product of M_i and M_j divided by the product of the magnitudes of the two vectors for normalization. This index depends only on the composition ratios of research expenditures on products by the two industries.

This index has the following characteristics.

(i) As shown in Figure 1 (b), the value of the index vanishes if there is no overlap in the research expenditure components classified by products and paid by the ith and jth industries.

(ii) If the ith and jth industries are both spending funds in the same product areas (as a simple example, if the ith industry is investing in the jth product area and the jth industry in the ith product area, as shown in Figure 1 (c)), then the index is positive ($r_{ij} < 1$, however) and its magnitude increases as the expenditure weights by the two industries in the common product area increase. When these two industries provide identical composition for the expenditures classified by products, the index is unity.

(iii) In other words, one can consider this index as an indicator of

product areas (technology fusion areas) in which two industries are both paying for research, thus strongly correlating the technologies of the two industries and likely leading to new technologies from such a combination (Figure 1 (d)).

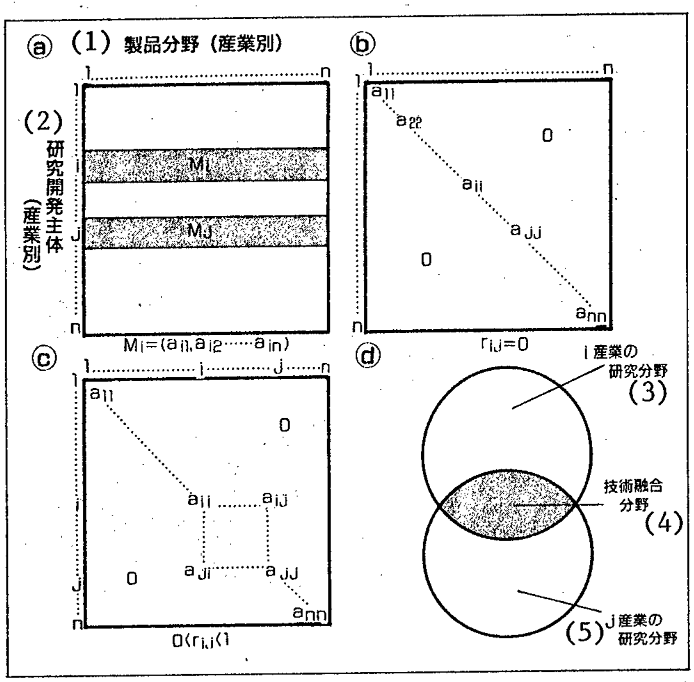

Figure 1. Significance of the technology fusion index.

Key to Figure 1:
(1) Products (by industry)
(2) Main source of research and development (by industry)
(3) Research area of the ith industry
(4) Technology fusion area
(5) Research area of the jth industry

Technology fusion indices were computed among all manufacturing industries from 1970 to 1984. In Figure 2, we plot and compare all combinations of the indices that are greater than 0.04. According to the figure, technology fusion was limited to within the same technology group, such as the chemical group, machinery group, metallurgy group, and electronics group, in 1970. In contrast, in 1984, technology fusion was also in progress between different technology groups, such as between the machinery group and electronics group and between the electronics group and chemical group.

For instance, the technology fusion index between the machinery industry and the communications and electronics (equipment) industry was only 0.03, but it jumped to 0.17 by 1984. This is probably a result of the advanced fusion between the machine technology and electronic technology through the applications of developing IC technology to small, electronic control devices.

As a result, the mechatronics industry, which manufactures high-performance robots and CNC [computer numerical control] machinery, has been created. Also, the technology fusion index between the ceramics industry and machine industry was only 0.02 in 1970 but reached 0.09 by 1984 through advanced structural materials, which resulted from fusion of technology for evaluating and applying fine ceramics (machine industry) and their manufacturing technology (ceramics industry).

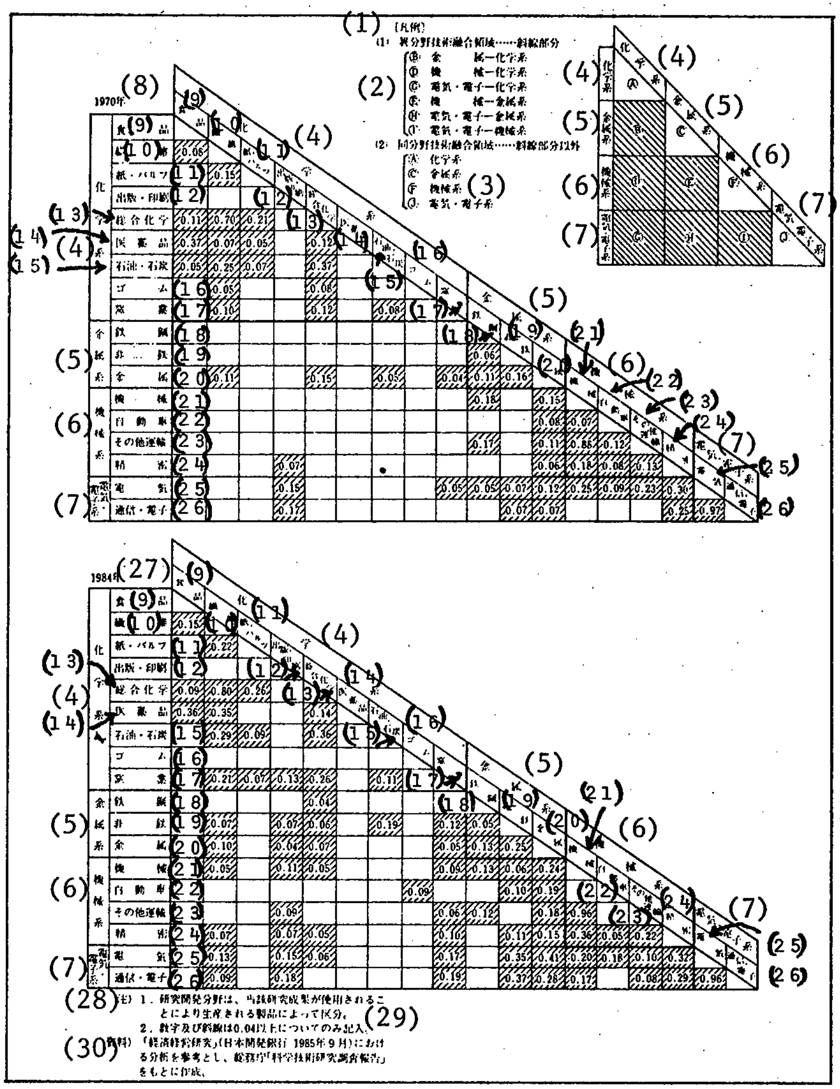

Figure 2. Technology fusion index matrix (1970-1984).

Key to Figure 2:
(1) Legend
(2) Shaded parts indicate technology fusion areas between different industry groups:

(B) Metallurgy group--chemical group (D) Machinery group--chemical group
(G) Electrical and electronics group--chemical group
(E) Machinery group--metallurgy group
(H) Electrical and electronics group--metallurgy group
(I) Electrical and electronics group--machinery group

(3) Unshaded parts indicate technology fusion areas within the same industry group:
(A) Chemical group
(C) Metallurgy group
(F) Machinery group
(J) Electrical and electronics group

(4) Chemical group
(5) Metallurgy group
(6) Machinery group
(7) Electrical and electronics group
(8) 1970
(9) Food [industry]
(10) Fiber
(11) Paper and pulp
(12) Publishing printing
(13) Comprehensive chemical
(14) Medical and pharmaceutical
(15) Petroleum and coal
(16) Rubber
(17) Ceramics
(18) Steel
(19) Nonferrous metals
(20) Metals
(21) Machinery
(22) Automobile
(23) Other transportation
(24) Precision machinery
(25) Electrical
(26) Communications and electronics
(27) 1984
(28) Footnote 1. Research and development areas were classified according to the products manufactured, using results from such research and development.
(29) Footnote 2. Numbers and shaded parts were indicated only when technology fusion indices were greater than 0.04.
(30) Source: The analysis in the "Economic Management Research" (Japan Development Bank, September 1985) was used, and this figure was prepared using the data in the "Science and Technology Research Survey Report" by the General Affairs Agency.

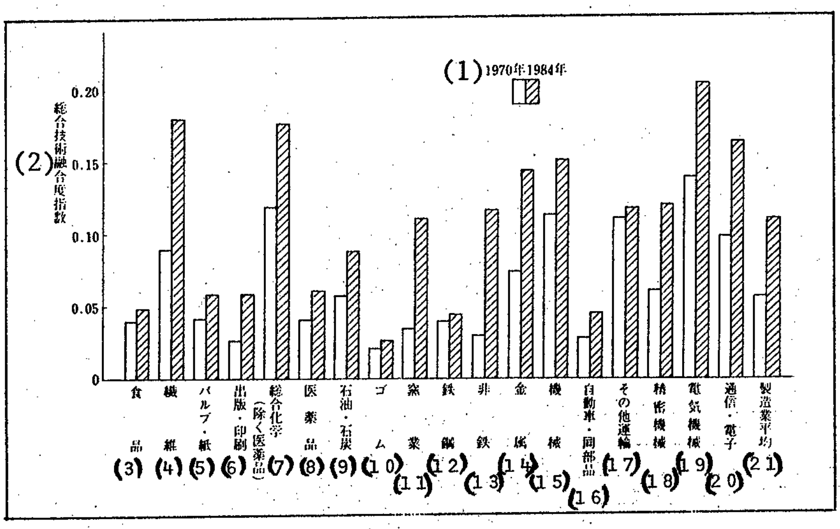

Figure 3. Trend of the comprehensive technology fusion index.

Key to Figure 3:

(1) 1970 [unshaded bars], 1984 [shaded bars]
(2) Comprehensive technology fusion index
(3) Food
(4) Fiber
(5) Pulp and paper
(6) Publishing and printing
(7) Comprehensive chemical (exclusive of medical and pharmaceutical supplies)
(8) Medical and pharmaceutical
(9) Petroleum and coal
(10) Rubber
(11) Ceramics
(12) Steel
(13) Nonferrous metals
(14) Metals
(15) Machinery
(16) Automobile and parts
(17) Other transportation
(18) Precision machinery
(19) Electrical machinery
(20) Communications and electronics
(21) Manufacturing industry average

Now, as a comprehensive indicator of the overall status of technology fusion between two different industries, we define a comprehensive technology fusion index of the ith industry as follows:

$$R_i = \sum_j^n r_{ij}/n, \qquad (i \neq j).$$

This comprehensive technology fusion index shows to what extent one industry has fused its technology with that of another industry on the average. Figure 3 shows the trend of the comprehensive index between 1970 and 1984. According to this figure, the index is increasing for all industries, particularly for the nonferrous metals industry (from 0.03 to 0.12), ceramics industry (from 0.04 to 0.11), and fiber industry (from 0.09 to 0.19).

The progress in technology fusion thus described has brought about the following changes in industrial research and development activities.

The first change is the diversification of industrial researchers. In Figure 4, we show the trend in the composition of research staff who were, for example, in the fiber, ceramics, and communications and electronics industries according to their specialities. The proportion of the research staff whose specialities coincided with the main business of their industries has uniformly decreased between 1970 and 1983, while the fraction of those who worked in topics other than their industries' main business has increased. This trend indicates that businesses have expanded research staff whose specialities are beyond their main business in order to create technology and knowledge of other fields within their own enterprise and integrate technologies.

The second change is the more aggressive attitude of businesses about cooperation between different industries. In Figure 5, we present in a matrix the expectations of each industry about exchange and cooperation with other industries concerning research and development. According to this figure, businesses that desire exchange and cooperation with different industries exist in very many areas. Examples of mutually expressed, relatively high

hopes are: the microelectronics area to match the communications and electronics industry with the inorganic and organic chemical industry, nonferrous metals industry, and machinery industry; the biotechnology area to match the medical and pharmaceutical industry with the food industry, fiber industry, and the inorganic and organic chemical industry; and the new materials area to match the automobile industry with the nonferrous metals industry and metal products industry.

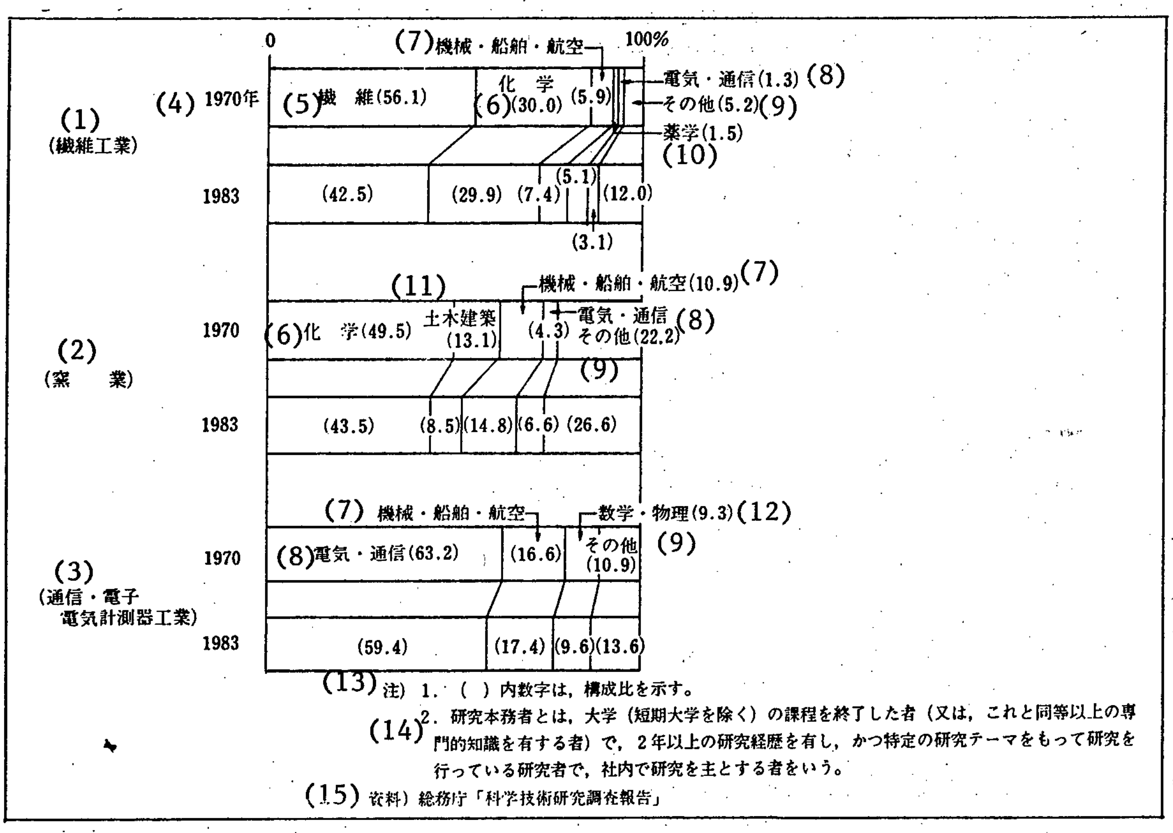

Figure 4. Trend of researchers according to industry and specialty.

Key to Figure 4:
(1) Fiber industry
(2) Ceramics industry
(3) Communication, electronics, and electrical gauge industry
(4) 1970
(5) Fiber
(6) Chemistry
(7) Machinery, shipbuilding, and aeronautics
(8) Electricity and communications
(9) Others
(10) Pharmacology
(11) Civil engineering and architecture
(12) Mathematics and physics
(13) Footnote 1. Numbers in parentheses are composition ratios.
(14) Footnote 2. Researchers are defined as those who graduated from college (exclusive of junior colleges) or have equivalent knowledge in a special

field, have engaged in two or more years of research on specific topics, and mainly conduct research in their companies.
(15) Data from the "Science and Technology Research Survey Report" by the General Affairs Agency.

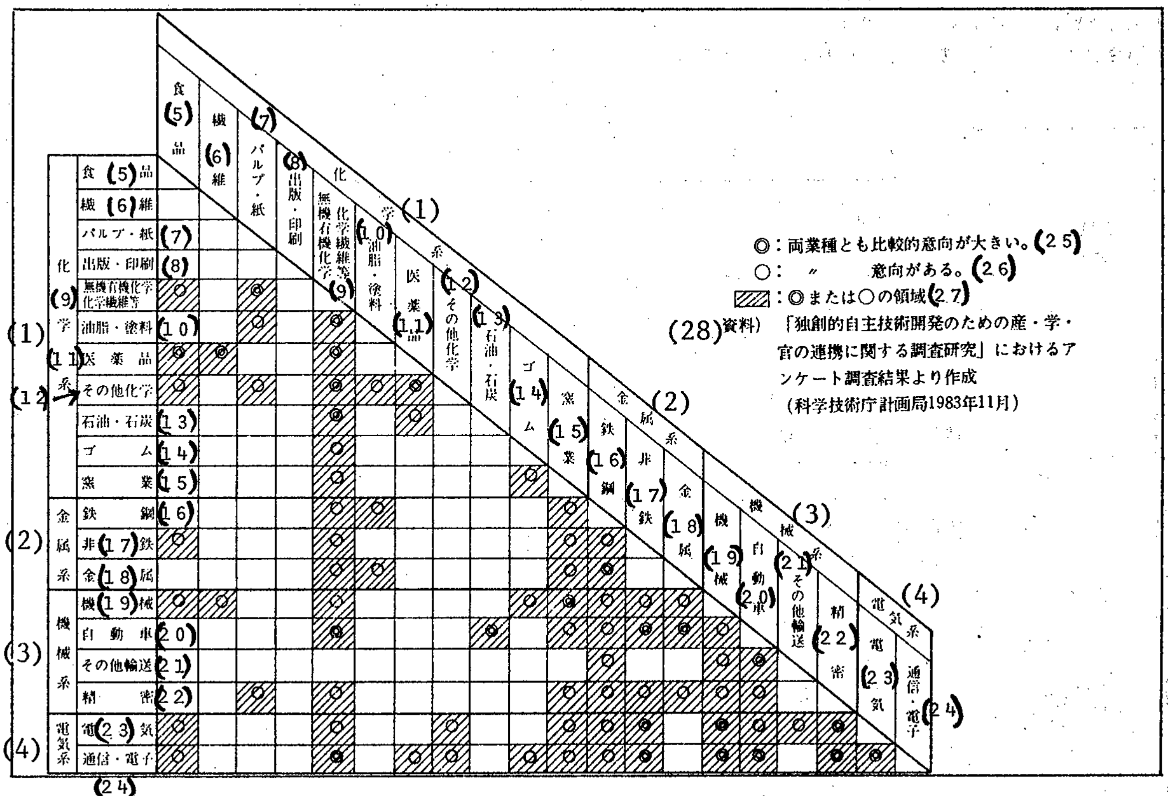

Figure 5. Outlook for technology exchange between different industries.

Key to Figure 5:
(1) Chemical group
(2) Metallurgy group
(3) Machinery group
(4) Electrical group
(5) Food [industry]
(6) Fiber
(7) Pulp and paper
(8) Publishing and printing
(9) Inorganic and organic chemical, chemical fibers
(10) Oil, fat, and paint
(11) Medical and pharmaceutical
(12) Other chemical
(13) Petroleum and coal
(14) Rubber
(15) Ceramics
(16) Steel
(17) Nonferrous metals
(18) Metals
(19) Machinery
(20) Automobile
(21) Other transportation
(22) Precision machinery
(23) Electrical
(24) Communications and electronics
(25) Both industries have relatively high expectations.
(26) Both industries have expectations.

(27) Shaded areas indicate double or single circle.
(28) Data from: Results of the "Survey of cooperation among industries, universities, and government agencies for unique and domestic technology development" (by the Planning Bureau, Science and Technology Agency, November 1983)

Wide-spread progress in the technology fusion described above implies creation of new technology fusion areas and will contribute to expanding new, promising areas for industries. At the same time, technological innovations in an industry are expected to effect more diverse areas than before through technological interaction among industries whose ties have been strengthened by technology fusion.

2. Progress in Fusion of Industries

The progress in technology fusion diversified businesses beyond the traditional domain of industries and stimulated cooperation among different industries, thus leading to fusion of industries.

For instance, we can study the diversification of the fiber industry (manufacturers of synthetic fibers) using reports on securities. The market share of the industry's main business, synthetic fibers, is in a downward trend. Hence, the industry used high-polymer technology, which is the core technology of the synthetic fiber industry, as its base and absorbed technologies from other fields, such as microelectronics, new materials, and biotechnology, through joint research with other firms and diversification of research staff. By discovering seeds for new technologies, the fiber industry has moved into newly fused industries such as high-polymer electronics materials, medical and pharmaceutical supplies, and carbon fibers.

In addition to this fusion of the supply side and the seed side, another type of fusion, which corresponds to a diversification of demand structure, is in progress.

For instance, industries, which are directly connected to consumer demands such as the fiber industry, housing industry, and the industry for daily commodities, are trying to create, provide and improve on fashion and designs that are adapted to Japanese sensitivity and emotion in response to the diversification of demand structure, new lifestyles, and the increased demand for living culture. Also, these industries are trying to expand and become new cultural industries that create living culture by simultaneously pursuing diversified and cultural market demands through the introduction of CAD [computer-aided design] and CAM [computer-aided manufacturing] and by improving supply efficiency through information technology. There are trends in these industries not only to incorporate cultural, added values into products, but also to directly provide services such as music classes, cooking classes and leisure clubs, thus integrating the supply of merchandise with cultural services. This trend of fusing manufacturing industries with service industries improves the cultural lifestyles of consumers.

This progress in the fusion of industries in both the demand and supply sides

is taking place because it has become difficult to pursue "the economics of scale" through mass production of a single merchandise, which has been popular in the recent years of the high growth period; rather, it has become relatively more profitable to produce a variety of merchandises together and pursue "the economics of scope." "The economics of scope" is a concept proposed by Boumol et al., who are pioneers of the contestability theory, which has attracted attention in the United States as a new theory of industrial organization. According to their definition,

$$C(X_1,X_2) < C(X_1) + C(X_2),$$

where X_1 and X_2 are manufactured quantities of products 1 and 2, respectively, and $C(X_1,X_2)$ is their cost function. In other words, the above expression indicates that the cost of simultaneously manufacturing and selling two products by a firm is less than the sum of the costs of manufacturing and selling each product separately.

The reasons for the advantages of "the economy of scope" are as follows. First, demands have diversified because people's awareness and value judgement have changed. Accordingly, financial and service markets have become more specialized and divided into small lots. On the supply side, the possibility for multiple use of stocked technical knowledge has been expanded through progress in technology fusion. [Finally,] with advanced information technology, systems that produce small quantities of many different products (such as FMS [flexible manufacturing system], CAD, CAM), which can respond to diverse demands, have become a reality.

3. Fusion of Creative Knowledge of Industrial Structure

In order to avoid creating voids in domestic industries as international division of labor takes place while approaching the twenty-first century, we must aggressively create new industries and plan a smooth transformation of the industrial structure from existing industries into new ones.

In this effort, it is particularly important to seek out new businesses in which management resources, such as technologies nurtured by existing businesses, can be utilized. For instance, according to a survey conducted by the Industrial Vitality Research Institute among the fiber, chemical, steel, and shipbuilding industries on the trend of lifetime employment and future business strategy, about one half of the surveyed firms have replied that they would aggressively move into [new] promising industries in the next five years. Moreover, 95 percent of the firms stated that "it is necessary to develop specific technical know-how, but we can sufficiently utilize existing technical knowledge," or "it is possible to fully utilize existing knowledge because there is enough overlap." This indicates a positive attitude towards using existing technology to move into new industries. The case of the American steel industry, which rapidly lost business vitality in the early eighties as a result of business divestitures into areas hardly related to their main business, is a good example of the importance of utilizing knowledge accumulated from existing technologies.

Therefore, it is necessary to promote expansion into new industries through future fusion of industries by pursuing various aspects of knowledge activities by the fused industries and by helping steady responses to diversified demands that result from changes in people's awareness and value judgements.

From this viewpoint, the following patterns of knowledge fusion are shown in the final report.

(1) Fusion Led by Technology

This is a pattern in which a new technological system is created by fusing the technological systems of different industries. Then, new frontiers of an industry, which depends on the new system, are expanded and the industry advances.

(Example 1) Noting that amino acids can memorize and transmit information, organic chemistry technology is combined with electronics technology to bring progress to the research and development of biochips.

(Example 2) Miniature, high-definition liquid crystal indicators are developed for practical use by combining the ultrahigh precision processing technology of the precision machinery industry and the technology for high performance liquid crystals that use organic compounds.

(Example 3) Technology for synthetic, new materials is developed by combining technologies for metals, fine ceramics, and new fiber materials.

(2) Fusion Led by Market

This is a pattern in which the creation of a new living culture progresses by fusing diverse market demands in the financial and service industries with efficient supply [to fulfill the demands] through cultural [advances] and information technology.

(Example 1) In the fiber industry (fabric industry), a computer system, which can create a million delicate shades from 40 basic colors and easily simulate their coordination, has been introduced to cope with delicate and diverse demands for [different] color tones of fabrics. With the introduction of such a system, it is now possible to efficiently choose and design color tones and quickly respond to diverse needs.

(Example 2) The automobile industry, seeking energy savings and fashion, is asking the steel industry for hard and thin steels that are easy to process. For this purpose, a facility that can control crystal structures by rapid heating and cooling using computer control technology has been developed.

In reality, the knowledge fusion shown in the above two patterns will interact with each other, take various forms of fusion, and lead to the development of new areas in industry.

Since the seventies, the Industrial Structure Council had already focused its attention on the role of information activities in economic development and advancing industrial structure. The council has been indicating the basic direction of industrial structure, such as the "concentration of knowledge" and "concentration of creative knowledge," as well as corresponding directions for the development of each industry. There is no need to repeat the fundamental importance of such directions. However, it is also true that more global views that cut across many industries must be emphasized in the future, since knowledge activities of industries are already developing into many directions as we have seen and industrial fusion is expected to progress further, in step with diversified demands.

In this sense, the "fusion of creative knowledge" is not in competition with the conventional concentration of knowledge, but the former is along the same direction as the latter, with the goal of intensifying diverse knowledge activities.

Of course, we cannot deny that this report may not have provided enough quantitative support, theoretical clarity or concrete [examples] due to statistical restrictions. We hope to have more discussions in the future so that the concepts introduced here will be accepted as guiding principles for medium- and long-term industrial structure policies.

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END